6

12

USARTL-TR-78-55C

LEVEL II

COMBUSTOR DESIGN CRITERIA VALIDATION
Volume III - User's Manual

H. C. Mongia, R. S. Reynolds
AiRESEARCH MANUFACTURING COMPANY OF ARIZONA
111 South 34th Street
Phoenix, Ariz. 85034

AD A0 66793

February 1979

Final Report for Period 2 JULY 1975 - 31 October 1978

Approved for public release;
distribution unlimited.

Prepared for

APPLIED TECHNOLOGY LABORATORY
U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
Fort Eustis, Va. 23604

79 03

APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

This report describes an effort undertaken to improve small gas turbine combustor design techniques. This analytical procedure is viewed as a significant step toward reducing the design and development time and the cost associated with future Army gas turbine combustors while simultaneously achieving a more durable and fuel-efficient design. The reader is referred to the report documentation page for a description of each of the three volumes of this report. It is considered worthy of widespread application with the turbine industry. Any critique or other response regarding its use should be addressed to this Laboratory.

Mr. Kent Smith of the Propulsion Technical Area, Aeronautical Technology Division, served as Project Engineer for this effort.

DISCLAIMER NOTICE

(19) TR-78-55C-VOL-3

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (18) USARTL TR-78-55C	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) COMBUSTOR DESIGN CRITERIA VALIDATION, VOLUME III. USER'S MANUAL		5. TYPE OF REPORT & PERIOD COVERED (9) Final Technical Report, 2 July 1975 - 31 October 1978
		6. PERFORMING ORG. REPORT NUMBER (14) 75-211682(38)-3
7. AUTHOR(s) (10) H. C. Mongia, R. S. Reynolds		8. CONTRACT OR GRANT NUMBER(s) (15) DAAJ02-75-C-0044
9. PERFORMING ORGANIZATION NAME AND ADDRESS AiResearch Manufacturing Co. of Arizona, 111 South 34th Street, Phoenix, Arizona 85034	404 496	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (16) 62209A 1F262209AH76 (17) 00 00 079 EK
11. CONTROLLING OFFICE NAME AND ADDRESS Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM) Fort Eustis, Virginia 23604		12. REPORT DATE (11) February 1979
		13. NUMBER OF PAGES 409
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (12) 411 p.		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Volume III of a three-volume report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Spray trajectory, evaporation rate, nozzle design, fuel-mixing rate, mean droplet size, reverse-flow annular combustor, liner wall temperature

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document, the User's Manual, is Volume III of the Combustor Design Criteria Validation Program. It contains general information, descriptions of analytical models, descriptions of associated computer codes, and illustrations of the various combustor models. Volume I of this report contains the results of the combustor element tests and analytical model validation which took place in Task I of the program. Volume II contains the results of Tasks II and III on the design, fabrication, and rig tests of two different reverse flow annular combustors (3 pps) designed to specific goals utilizing the analytical procedures.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

404 496

TABLE OF CONTENTS

TABLE OF CONTENTS (Contd)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Contd)

LIST OF TABLES

I. INTRODUCTION

GENERAL INFORMATION

The present program represents an extension and refinement of the previous effort with specific application to the design requirements of advanced, small, high-temperature-rise combustors for aircraft engines in the 2- to 5-pound-per-second (0.91- to 2.27-kilogram-per-second) flow range. This program was performed for the Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), Ft. Eustis, Virginia by the AiResearch Manufacturing Company of Arizona during the period July, 1975, to October, 1978. The program is documented in this three-volume final report.

OBJECTIVE

The primary objective of this program was to further develop and validate existing analytical combustor design procedures that can be used to significantly shorten the design and development cycle of small advanced gas turbine engine combustors. Descriptions of the combustor analytical models, element tests and model validations are presented in Volume I.

The basic approach of the program consisted of a concentrated analytical treatment of key combustion phenomena affecting combustor performance complemented by rig tests. The rig test culminated in a complete series of performance mapping to validate the empirical/analytical combustor design procedure in an environment matching an actual operating engine.

The program was initially comprised of four technical tasks:

Task I - Analytical-Model Refinement

Task II - Full-Scale Combustor Design, Fabrication, and Preliminary Tests

Task III - Combustor-Performance Mapping

Task IV - Limited Modification and Retest

The Task I technical effort is described in Volume I. A complete description of the Task II and Task III activities is presented in Volume II. The computer codes for combustor design that evolved from that effort are fully documented in Volume III of this report. The combustor performance goals were achieved in Tasks II and III; thus Task IV was cancelled.

The computer models are based upon the numerical solution of the governing aero/thermo equations applicable to turbo-propulsion combustor environment, and are, therefore, applicable for analyzing internal flow field of can, can-annular and annulus combustor geometries. Both the inline and reverse-flow combustor configurations can be analyzed.

The cost-effectiveness of the empirical/analytical design procedure was to be demonstrated by undertaking the design and development testing of two full-scale annular combustors based on the following engine/combustor configurations, parameters and goals:

1. Engine/Component Configurations.

- Annular-combustor configurations
- Centrifugal compressor (last stage)
- First-stage axial turbine
- Nonregenerative cycle

2. Parameters and Goals.

- Engine airflow, W_{a3} = 2.87 pounds per second (1.30 kg/s)
- Combustor inlet pressure (P_3) = 10 atmospheres
- Compressor efficiency = 78.4 percent (total-to-static)
- Combustor inlet temperature = 660°F (622°K)
- Combustion efficiency = 99.5 percent (100 percent power) = 98.0 percent (5 percent power)
- Combustor pressure loss $\frac{P_{T3}-P_{T4}}{P_{T3}}$ = 3 percent
- Combustor discharge temperature (T_{4avg}) = 2300°F (1533°K)
- Maximum pattern factor (PF) ≤ 0.23

  where $$PF = \frac{T_{4\ max} - T_{4avg}}{T_{4avg} - T_3}$$
- Average radial temperature profile compatible with typical turbine blade requirements
- Maximum radial pattern factor (RPF) ≤ 0.075

  where $$PF = \frac{T_{4\ avg\ rad\ max} - T_{4\ avg}}{T_{4\ avg} - T_3}$$

  $T_{4\ avg\ rad\ max}$ = peak value of the circumferentially averaged radial temperature profile

- Good light-off/relight capability to 20,000 feet (6091 meters) altitude and ambient-temperature conditions per MIL-E-5007D Paragraph 3.2.5.1 (dated 15 October 1973)

- No visible carbon formation with hot fuel or at high-altitude conditions

- Multifuel capability, including JP-4 and JP-5

- Fuel contamination tolerance per MIL-E-8593A, Table X with filtration to 10 microns

- The combined CO and HC exhaust emissions will be sufficiently low to meet the previously noted combustion efficiency goals at 100- and 5-percent rated power. The NO_x LTO emissions level will be at or below the 1979 EPA NO_x standards. The maximum smoke number will be below the threshold of the exhaust plume visibility

- Acceptable component temperature levels and gradients to ensure long combustion system life and reliability

- Reasonable cost and weight

SUMMARY

A complete description of the following six combustor analytical models, associated computer codes, and users manuals are given in this report.

- Annulus-flow model

- Combustor-performance model

- Liner-cooling model

- Transition-liner mixing model

- Emissions model

- Fuel-insertion model

The annulus-flow model is used to compute airflow distribution around the combustor liner and pressure drop. The information provided by this model on jet velocities and efflux angles is used for specifying the boundary conditions of the internal-flow computer models.

A 3-D reacting recirculating-flow model is used for computing internal profiles of velocity components, chemical species, and temperature of a given combustor design. Effects of detail-design changes can be analytically predicted in regard to combustion efficiency, exhaust temperature quality, and lean blowout.

Two-dimensional parabolic programs are used for predicting liner-wall-temperature levels, mixing rate in the combustor transition liner of reverse-flow annular combustors, and gaseous emissions. A fuel-insertion model is used to compute mean droplet size and size distribution of pressure atomizers, including simplex, duplex, and air-assist pressure atomizers, and airblast nozzles. The model is also used to compute spray trajectory and evaporation rate of a given nozzle design in a specified flow field.

The use of these models is illustrated in Section IV by a worked-out illustration of a simple combustor.

II. DESCRIPTION OF ANALYTICAL MODELS

The six combustor analytical models are described in this section. The relevent computer codes are described in Section III. The use of these models is illustrated by an example in Section IV.

ANNULUS-FLOW MODEL

An annulus-flow model is used to compute pressure losses, annulus Mach number and associated air velocity, and airflow distribution around the combustor liner.

A one-dimensional analysis of the plenum annulus is conducted based upon the generalized one-dimensional continuous flow-analysis approach of Shapiro[1]. The analysis considers the effect of area change, wall friction, drag introduced by inserted obstacles such as fuel nozzles and service struts, heat transfer from the liner wall, and injection or extraction of air from the annulus. The analysis is valid for constant specific heat and molecular weight.

Following the approach of Shapiro for a small control volume around a point P located at a distance "X" from the compressor discharge, as shown in Figure 1, the following three working relations are obtained for Mach number M, stagnation pressure P_o, and static temperature T.

---

[1] Shapiro, Ascher H., "The Dynamics and Thermodynamics of Compressible Fluid Flow, Vol. I", Chapter 8, The Ronald Press Company, New York (1953).

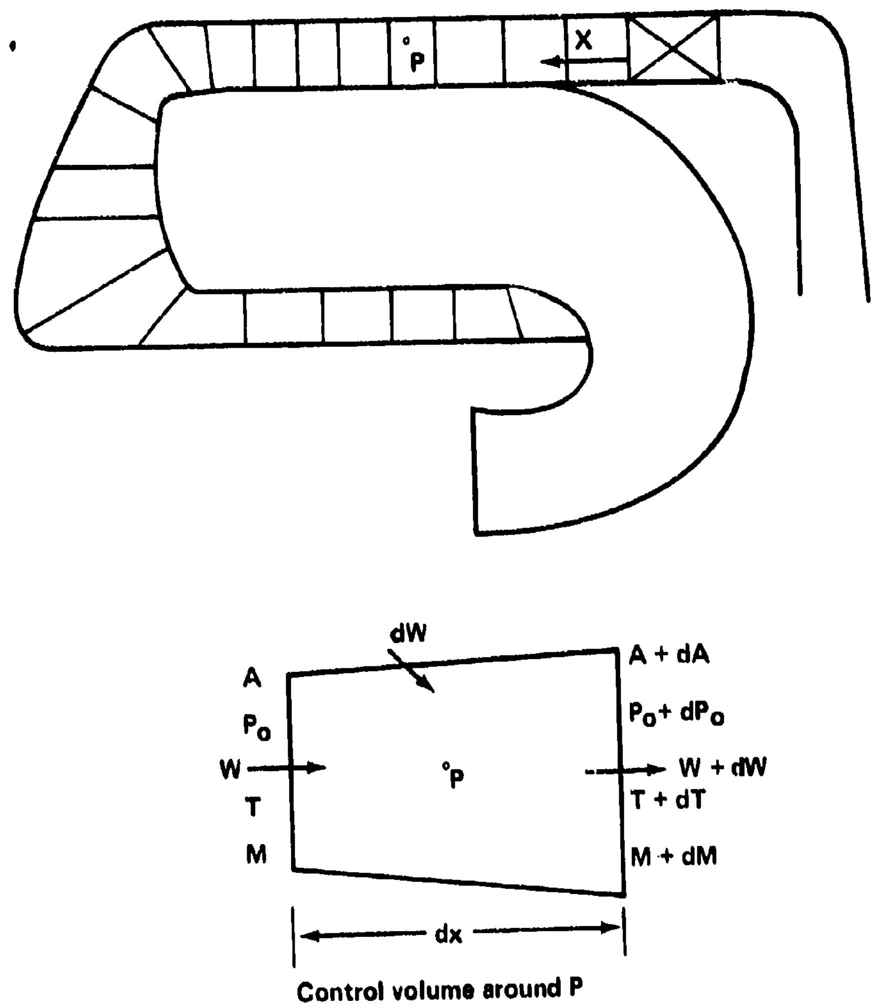


Figure 1. Control Volumes for Annulus-Flow Model.

$$\frac{dM^2}{M^2} = -2\,\frac{\left(1+\frac{\gamma-1}{2}M^2\right)}{1-M^2}\left[\frac{dA}{A} + \left(\frac{1+\gamma M^2}{2}\right)\frac{dT_o}{T_o} + \frac{\gamma M^2}{2}\left(4f\,\frac{dx}{D_H} + \frac{dF}{\frac{1}{2}\gamma pAM^2} - 2y\,\frac{dW}{W}\right)\right.$$

$$\left. + \left(1+\gamma M^2\right)\frac{dW}{W}\right] \qquad (1)$$

$$\frac{dp_o}{p_o} = -\frac{\gamma M^2}{2}\left[\frac{dT_o}{T_o} + 4f\,\frac{dx}{D_H} + \frac{dF}{\frac{1}{2}\gamma pAM^2} + 2(1-y)\,\frac{dW}{W}\right] \qquad (2)$$

$$\frac{dT}{T} = \frac{M^2}{1-M^2}\left[(\gamma-1)\,\frac{dA}{A} + \left(\frac{1-\gamma M^2}{M^2}\right)\left(1+\frac{\gamma-1}{2}M^2\right)\frac{dT_o}{T_o}\right.$$

$$- \frac{\gamma}{2}(\gamma-1)\,M^2\left(4f\,\frac{dx}{D_H} + \frac{dF}{\frac{1}{2}\gamma pAM^2} - 2y\,\frac{dW}{W}\right) \qquad (3)$$

$$\left. - (\gamma-1)\left(1+\gamma M^2\right)\frac{dW}{W}\right]$$

Where:

- A = Flow area
- D_H = Mean hydraulic diameter
- f = Coefficient of skin friction
- F = Drag force by inserted obstacles
- T = Static gas temperature

W = Mass flow rate

y = Injected mass axial velocity/mainstream velocity

γ = Ratio of specific heats

The above set of equations is written for each of the control volumes, shown schematically in Figure 1, applicable to a reverse-flow combustor geometry. Appropriate expressions are used for skin friction coefficient and drag introduced by fuel nozzles and other obstacles in the flow path. The remaining unknown variable dW, which will be negative for the flow through various orifices, is calculated by using the following approach.

The orifice configurations used in a combustor liner can be broadly divided into two basic categories.

- Configurations such as swirlers, primary pipes, and venturi sections which are either difficult to handle analytically or their flow rates are less affected by approach conditions.

- Liner orifices, including flush port, plunged holes, and scooped ports are affected by approach conditions and are amenable to analytical approach for predicting flow rates, jet velocities, and efflux angles.

The first type of ports are handled by specifying discharge coefficients, whereas the liner orifices are handled by using a modified analytical approach described by Gurevice[2]. The Gurevice approach is based upon a 2-D potential flow solution of a problem shown schematically in Figure 2.

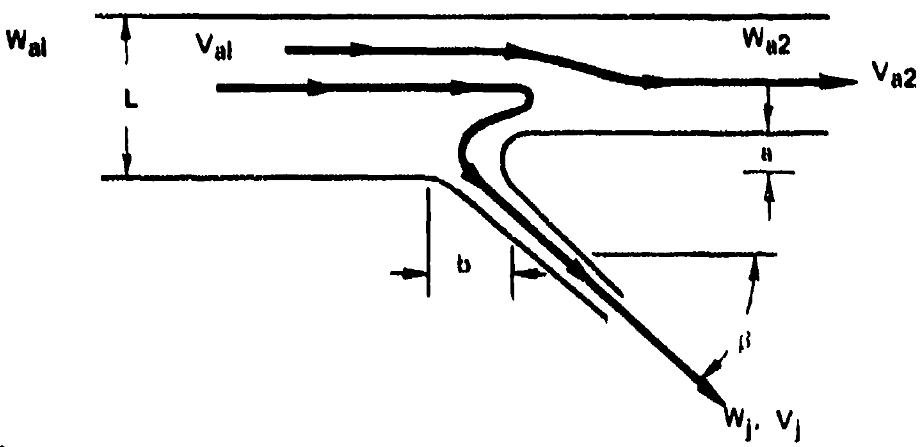
For an infinitely long slot of width b, the following three relations are obtained for the three unknowns, namely n, β and C_D.

[2]Gurevich, M.I., "Theory of Jets in an Ideal Fluid", Pergamon Press, pp 52-59.

$$c = \cos\beta/(1-\tfrac{1}{2n}) \tag{4}$$

$$\begin{aligned}\frac{b}{L} = \frac{1}{\pi} \Bigg[& \frac{\pi\sin\beta}{n} - \frac{\cos\beta}{n} \ln\left(\frac{1+\cos\beta}{1-\cos\beta}\right) \\ & + \frac{\left(1-\frac{1}{2n}\right)^2 + \cos^2\beta}{\left(1-\frac{1}{2n}\right)\cos\beta} \ln\left|\frac{\left(1-\frac{1}{2n}\right)+\cos\beta}{\left(1-\frac{1}{2n}\right)-\cos\beta}\right| \\ & \frac{\left(1-\frac{1}{2n}\right)^2 + \left(1-\frac{1}{n}\right)^2\cos^2\beta}{\left(1-\frac{1}{2n}\right)\cos\beta} \ln\left|\frac{\left(1-\frac{1}{2n}\right)+\left(1-\frac{1}{n}\right)\cos\beta}{\left(1-\frac{1}{2n}\right)-\left(1-\frac{1}{n}\right)\cos\beta}\right| \Bigg] \frac{\cos\beta}{\left(1-\frac{1}{2n}\right)}\end{aligned} \tag{5}$$

$$C_D = \frac{L}{b}\left(\frac{2\cos\beta}{2n-1}\right) \tag{6}$$



Where:

- a/L = annulus width change/upstream width
- b/L = slot width/upstream annulus width
- n = annulus upstream flow rate/slot flow rate, W_{a1}/W_j
- c = upstream annulus velocity/slot velocity, V_{a1}/V_j
- β = jet efflux angle
- C_D = discharge coefficient

Figure 2. Liner Port Model Schematic.

These equations are applied to combustor liner orifices by maintaining area similarity through the following relationships:

$$b/_{L} = A_H/A_{ea}$$

where A_H = orifice area ($= \frac{\pi}{4} D^2$ for circular hole)

A_{ea} = effective annulus area with boundary-layer blockage effects

For a given application, the annulus upstream conditions and the static pressure inside the combustor must be specified. With the above equations, an orifice can be sized to pass a specified flow rate, or the flow through a specified orifice can be calculated. The procedure for each is outlined as follows.

For given values of annulus and orifice flow rates and velocities, c can be calculated and then the efflux angle can be found from Equation 4. For the special case where all annulus flow passes through the orifice, n = 1 and

$$\cos \beta = c/2$$

If the orifice flow is a negligible portion of the annulus flow, n approaches infinity,

$$\cos \beta = c$$

After the value of β is obtained, Equation 5 can be used to calculate b/L and A_H/A_{ea} from Equation 7; then from Equation 6, C_D can be calculated.

For the alternate problem, with the orifice specified, the above procedure is used in an iterative solution starting with an estimated flow rate (value of n). The iteration is continued until n converges to a small difference between iterations.

Such an approach has given good correlation with measure C_D[3] data of the circular orifices, as shown typically in Figure 3. For plunged orifices and the metering orifices of film-cooling geometries, the approach gave only qualitative agreement. However, by multiplying the computed C_D values by 1.48 and 1.4, and by assuming β equal to 80- and 0-degrees, respectively, for the plunged orifices and the cooling slot, the approach gave good agreement with the data, as shown in Figure 3.

With the above procedure for computing dW appearing in Equations 1, 2, and 3, it is now possible to write a set of equations for each of the control volumes around the combustor liner, as shown schematically in Figure 1. These equations are solved iteratively to compute isothermal combustor-pressure drop. To this can be added pressure drop due to heat addition which gives combustor total pressure drop.

3-D COMBUSTOR PERFORMANCE MODEL

A 3-D elliptic, reacting-flow model is used for calculating internal flow field of gas turbine combustors. The model solves governing equations for the following variables, as described in Paragraph 6 below:

- Axial, radial, and swirl velocity components
- Specific enthalpy and temperature
- Turbulence kinetic energy and dissipation rate

[3] Hunter, S. C., K. M. Johansen, H. C. Mongia, and M. P. Wood, "Advanced, Small, High-Temperature-Rise Combustor Program, Volume II: Analytical Mode Derivation and Combustor-Element Rig Tests (Phases I and II)", AD778766 (1974).

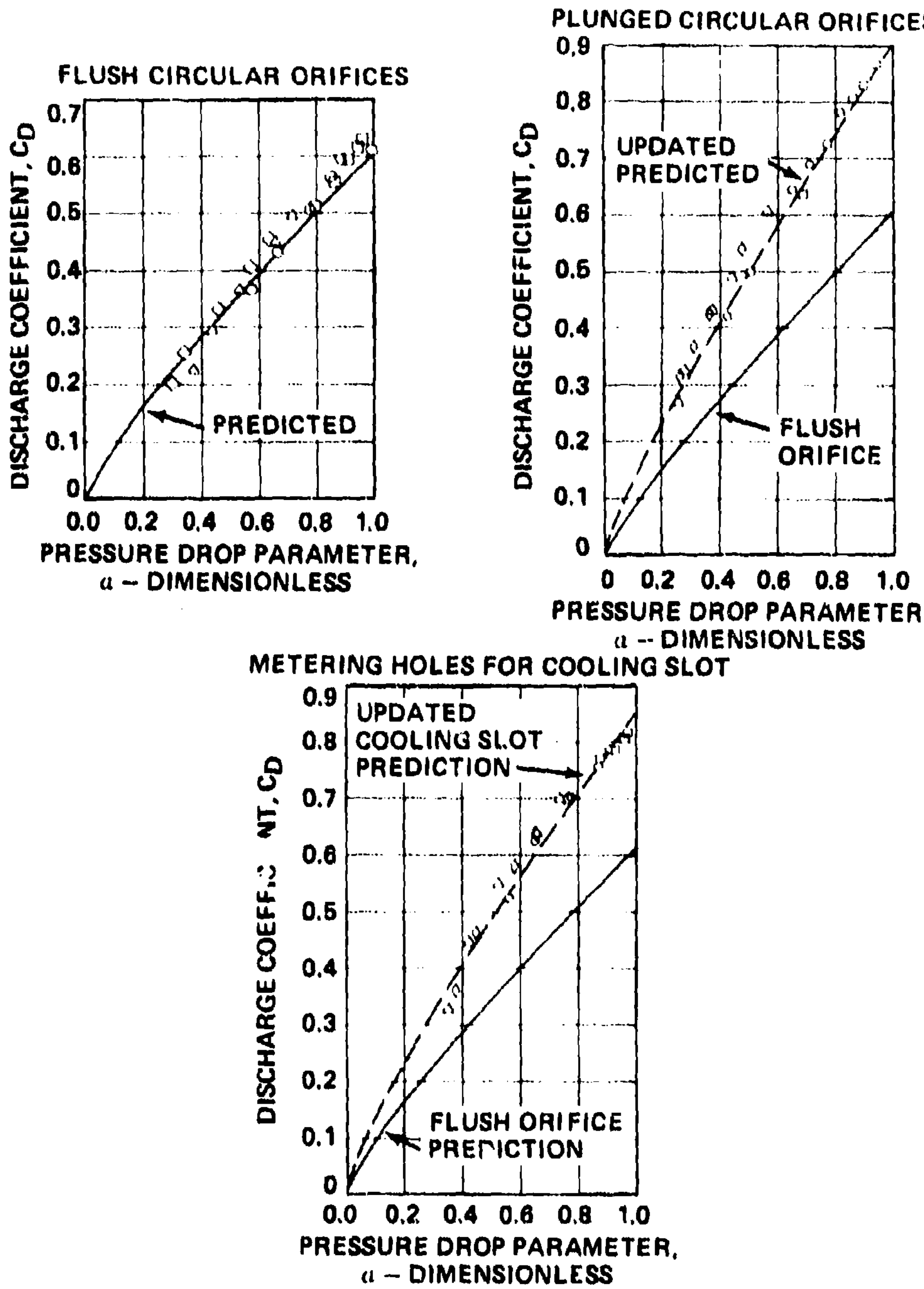


Figure 3. A Typical Comparison Between Prediction and Measured C_D.

- Unburned fuel, CO, and composite fuel fraction
- Radiation-flux vectors
- Spray combustion

Paragraphs 7 and 8 below give a brief description of the boundary conditions and the numerical scheme used for solving the set of nonlinear coupled partial differential equations.

1. Equations of Continuity, Momentum, and Enthalpy.

a. Continuity.

$$\text{div}\ (\rho\vec{V}) = \dot{m}'''_{spray} \tag{8}$$

b. x-Momentum.

$$\text{div}\ (\rho\vec{V}u - \mu_{eff}\ \text{grad}\ u) = -\frac{\partial p}{\partial x} - \frac{2}{3}\frac{\partial}{\partial x}(\mu_{eff}\text{div}\ \vec{V}) + \frac{\partial}{\partial x}(\mu_{eff}\frac{\partial u}{\partial x}) + \frac{1}{r}\frac{\partial}{\partial r}(\mu_{eff}\ r\frac{\partial v}{\partial x}) + \frac{1}{r}\frac{\partial}{\partial \theta}(\mu_{eff}\frac{\partial w}{\partial x}) + S^u_{spray} \tag{9}$$

c. y-Momentum.

$$\text{div}\ (\rho\vec{V}v - \mu_{eff}\ \text{grad}\ v) = -\frac{\partial p}{\partial r} - \frac{2}{3}\frac{\partial}{\partial r}(\mu_{eff}\ \text{div}\ \vec{V}) + \frac{\partial}{\partial x}(\mu_{eff}\frac{\partial u}{\partial r}) + \frac{1}{r}\frac{\partial}{\partial r}(\mu_{eff}\ r\frac{\partial v}{\partial r}) + \frac{1}{r}\frac{\partial}{\partial \theta}[\mu_{eff}(\frac{\partial w}{\partial r} - \frac{w}{r})] - 2\frac{\mu_e}{r}(\frac{1}{r}\frac{\partial w}{\partial \theta} + \frac{v}{r}) + \frac{\rho w^2}{r} + S^v_{spray} \tag{10}$$

d. θ-Momentum.

$$\text{div}\,(\rho\vec{V}w - \mu_{eff}\,\text{grad}\,w) = -\frac{1}{r}\frac{\partial p}{\partial\theta} - \frac{2}{3}\,\frac{\partial}{r\partial\theta}\,(\mu_{eff}\,\text{div}\,\vec{V})$$

$$+ \frac{\partial}{\partial x}\left(\frac{\mu_{eff}}{r}\frac{\partial u}{\partial\theta}\right) + \frac{1}{r}\frac{\partial}{\partial r}\left[\mu_{eff}\,r\,\left(\frac{1}{r}\frac{\partial v}{\partial\theta} - \frac{w}{r}\right)\right]$$

$$+ \frac{1}{r}\frac{\partial}{\partial\theta}\left[\frac{\mu_{eff}}{r}\left(\frac{\partial w}{\partial\theta} + 2v\right)\right] - \frac{\rho v w}{r} + \frac{\mu_{eff}}{r}\left(\frac{\partial w}{\partial r} + \frac{\partial v}{r\partial\theta} - \frac{w}{r}\right) \qquad (11)$$

$$+ S^{w}_{spray}$$

e. Specific enthalpy.

$$\text{div}\,\left(\rho\vec{V}\,h - \frac{\mu_{eff}}{P_{r_{eff}}}\,\text{grad}\,h\right) = S_h \qquad (12)$$

where

S_h represents the sum of all the enthalpy source terms for radiation and spray evaporation

Definition of variables are:

$\vec{V}$ = Net gas velocity vector

u,v,w = Velocity components along x, radial and circumferential directions

x,y,θ = Axial, radial and circumferential coordinates

p = Static pressure

h = Static specific enthalpy

S^{u}_{spray}, S^{v}_{spray}, S^{w}_{spray} = Momentum transfer from spray to the gas phase u, v and w - momentum equations

$\dot{m}'''_{spray}$ = spray evaporation/combustion rate per unit volume

$$\mathrm{div}\,(\rho\vec{V}\phi) = \frac{1}{r}\left[\frac{\partial}{\partial x}(r\rho u\phi) + \frac{\partial}{\partial r}(r\rho v\phi) + \frac{\partial}{\partial \theta}(\rho w\phi)\right]$$

$$\mathrm{div}\,(\mu\ \mathrm{grad}\ \phi) = \frac{1}{r}\left[\frac{\partial}{\partial x}\left(r\mu\frac{\partial\phi}{\partial x}\right) + \frac{\partial}{\partial r}\left(r\mu\frac{\partial\phi}{\partial r}\right) + \frac{\partial}{\partial\theta}\left(\frac{\mu}{r}\frac{\partial\phi}{\partial\theta}\right)\right]$$

The effective viscosity μ_{eff} is given by $\mu_{eff} = \mu_\ell + \mu_t$

where μ_ℓ and μ_t are the molecular and turbulent viscosities of the fluid, respectively.

2. Turbulence Model.

The turbulent viscosity μ_t is calculated by using a two-equation turbulence model that solves governing equations for the turbulence kinetic energy (k) and the dissipation rate (ϵ). The governing equations for k and ϵ are:

$$\mathrm{div}\,(\rho\vec{V}k - \Gamma_{k,eff}\ \mathrm{grad}\ k) = G_k - \rho\varepsilon \tag{13}$$

$$\mathrm{div}\,(\rho\vec{V}\varepsilon - \Gamma_{\varepsilon,eff}\ \mathrm{grad}\ \varepsilon) = (C_1G_k - C_2\rho\varepsilon)\,\frac{\varepsilon}{k} \tag{14}$$

where

$$G_k = \mu_t\Big[\,2\,\Big\{\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial r}\right)^2 + \left(\frac{\partial w}{r\partial\theta} + \frac{v}{r}\right)^2\Big\} + \left(\frac{\partial w}{\partial x} + \frac{\partial u}{r\partial\theta}\right)^2 + \left(\frac{\partial u}{\partial r} + \frac{\partial v}{\partial x}\right)^2 + \left(\frac{\partial w}{\partial r} + \frac{\partial v}{r\partial\theta} - \frac{w}{r}\right)^2\Big] \tag{15}$$

$$\Gamma_{k,eff} = \mu_{eff}/\sigma_{k,eff}$$
$$\Gamma_{\varepsilon,eff} = \mu_{eff}/\sigma_{\varepsilon,eff} \tag{16}$$

$$\mu_t = C_D\ \rho\ k^2/\varepsilon$$

C_D, C_1, and C_2 are constants. $\Gamma_{k,eff}$, $\Gamma_{\epsilon,eff}$, $\sigma_{k,eff}$ and $\sigma_{\epsilon,eff}$ are the effective exchange coefficients and Schmidt numbers for k and , respectively.

The k-ϵ turbulence model is moderate in complexity and is considered to be superior to other models having a similar degree of complexity. This model has been extensively used by many investigators and has proved to be adequate in a wide range of flow conditions. More advanced turbulence models, such as those based upon the Reynolds-stress modeling approach, are not yet fully developed to warrant their use in recirculating flow-field problems as encountered in gas-turbine combustors. In addition, such an approach will appreciably increase the computation effort.

Recommended values for the constants appearing in the above equations are

$$C_D = 0.09$$

$$C_1 = 1.44$$

$$C_2 = 1.92$$

$$\sigma_{k,eff} = 0.9$$

$\sigma_{\epsilon,eff}$ is calculated from

$$\sigma_{\epsilon,eff} = \frac{k^2}{(C_2 - C_1) C_D^{1/2}}$$

where k is the vonKarman constant taken to be equal to 0.42.

3. Chemical Species Equations.

A two-step kinetic scheme is used as represented by Equations 18 and 19.

$$C_x H_y + \left(\frac{x}{2} + \frac{y}{4}\right)(O_2 + n\, N_2) \rightarrow x\, CO + \frac{y}{2}\, H_2O + n\left(\frac{x}{2} + \frac{y}{4}\right) N_2 \quad (18)$$

$$x\, CO + \frac{x}{2}\,(O_2 + n\, N_2) \rightarrow x\, CO_2 + n\,\frac{x}{2}\, N_2 \quad (19)$$

Stoichiometric oxygen-to-fuel and oxygen-to-CO ratios for the first and the second reactions are given by

$$i_1 = \frac{32 \left(\frac{x}{2} + \frac{y}{4}\right)}{(12\ x + y)}$$

$$i_2 = 0.571$$

Combining Equations 18 and 19, one obtains overall stoichiometry equation as

$$C_xH_y + \left(x + \frac{y}{4}\right) (O_2 + n\ N_2) \rightarrow x\ CO_2 + \frac{y}{2}\ H_2O + n\left(x + \frac{y}{4}\right)N_2 \qquad (20)$$

The corresponding stoichiometric oxygen-to-fuel ratio is

$$i = \frac{32\left(x + \frac{y}{4}\right)}{(12\ x + y)}$$

Governing equations for fuel and CO mass fractions are:

$$\text{div}\ (\rho\vec{V}m_{fu} - \Gamma_{fu,eff}\ \text{grad}\ m_{fu}) = \dot{m}'''_{evap} - R_{fu} \qquad (21)$$

$$\text{div}\ (\rho\vec{V}m_{CO} - \Gamma_{CO,eff}\ \text{grad}\ m_{CO}) = -\ R_{CO} \qquad (22)$$

where R_{fu} and R_{CO} are rate of oxidation of fuel and CO in accordance with the combustion model explained in paragraph a. m'''_{evap}, is the rate of spray evaporation per unit volume computed in accordance with the spray combustion model description in Paragraph 5.

Equations similar to the above are required for O_2, CO_2, and H_2O. However, by using Shvab-Zeldovich approximation[4], one needs to solve only one more equation for composite fuel fraction, ϕ_{fuox}

[4]Williams, F. A., "Combustion Theory", Addison-Wesley Publishing Company, Inc. (1965).

$$\operatorname{div}\left(\rho\vec{V}\phi_{fuox} - \Gamma_{fuox}\,\phi_{fuox}\right) = \dot{m}'''_{evap} \tag{23}$$

where $\phi_{fuox} = \dfrac{\phi - \phi_A}{\phi_F - \phi_A}$

where $\phi = m_{fu} - \dfrac{m_{ox}}{i}$

ϕ_A and ϕ_F are the values of ϕ for air and fuel streams, respectively.

Knowing the amount of fuel burned ($FB = \phi_{fuox} - m_{fu}$), the concentrations of CO_2, O_2, and H_2O are given by

$$m_{CO_2} = 44\,\frac{x\ FB}{(12 + y)} - \frac{44}{28}\,m_{CO}$$

$$m_{ox} = i\ m_{fu} + i_2\ m_{CO} + 0.232 - (0.232 + i)\,\phi_{fuox}$$

$$m_{H_2O} = \frac{18\ y\ FB}{2\,(12 + y)}$$

Mass fraction of N_2 is given by

$$m_{N_2} = 1 - (m_{ox} + m_{fu} + m_{CO} + m_{CO_2} + m_{H_2O})$$

a. <u>Calculation of Reaction Rates</u>.

Equations are needed for oxidation rates of fuel and CO, i.e., R_{fu} and R_{CO}. The turbulent reactive flow is an area of intensive research, and a number of models have been proposed to predict burning rate of fuel in turbulent environments. A simple model is used in the present study as explained in the following paragraphs.

The rate of oxidation of fuel is determined by the minimum of the following three equations:

$$R_{fu,ch} = k_1 \rho^{1.5} m_{ox} m_{fu}^{\frac{1}{2}} e^{\left(-\frac{E_1}{R_T}\right)} \quad (24a)$$

$$R_{fu,turb} = C_{R_1} \rho m_{fu} \epsilon/k \quad (24b)$$

$$R_{fuox,turb} = C_{R_1} \rho \frac{m_{ox}}{i_1} \epsilon/k \quad (24c)$$

Here, Equation 24a is the rate of fuel oxidation as controlled by chemical kinetics. Generally, a bimolecular Arrhenous expression is assumed for this reaction. However, the Task I reacting-flow mapping data was best correlated by using Equation 24a in conjunction with Equations 24b and 24c.

Equation 24b is based upon the eddy-breakup model of Spalding[5] and expresses the rate of fuel oxidation as influenced by turbulence intensity and scale, and concentration of unburned fuel. This model is applicable to premixed flames. Since combustion in gas-turbine combustors is neither fully premixed nor entirely diffusion controlled, Equation 24c is postulated, similar to Equation 24, which determines the rate of fuel oxidation as controlled by the availability of the oxygen. The constant i_1 appears from stoichiometry of the chemical Equation 18. One could use i instead of i_1 without any loss of generality, because the empirical constant C_{R_1} will simply be different.

The rate of oxidation of CO is similarly the minimum of the following three equations:

$$R_{CO,ch} = k_2 \rho^2 m_{CO} m_{ox} e^{-\left(\frac{E_2}{R_T}\right)} \quad (25a)$$

$$R_{CO,turb} = C_{R_2} \rho m_{CO} \epsilon/k \quad (25b)$$

$$R_{CO_{ox,turb}} = C_{R_2} \rho \frac{m_{ox}}{i_2} \epsilon/k \quad (25c)$$

[5]Spalding, D. B., "Mixing and Chemcial Reaction in Steady Confined Turbulent Flames", Thirteenth Symposium (International) on Combustion, The Combustion Institute, 1971.

4. Radiation Model.

A six-flux radiation model based upon the Schuster-Hamaker approximation[6,7] is used in the present program. It should be noted that, as pointed out by Siddall,[8] other flux model approximations such as Milne-Eddington and Schuster-Schwarzschild can be represented by the same form of flux equations with constants being different. Therefore, the user can modify the flux equations with relative ease.

The differential equations describing the variations of the fluxes along the six directions are:

$$\frac{d}{dx}\,(I_{x+}) = -\,(a + s)\,I_{x+} + aE + \frac{s}{6}\,I \tag{26}$$

$$\frac{d}{dx}\,(I_{x-}) = (a + s)\,I_{x-} - aE - \frac{s}{6}\,I \tag{27}$$

$$\frac{1}{r}\,\frac{d}{dr}\,(r\,I_{r+}) = -\,(a + s)\,I_{r+} + \frac{I_{r-}}{r} + a\,E + \frac{s}{6}\,I \tag{28}$$

$$\frac{1}{r}\,\frac{d}{dr}\,(r\,I_{r-}) = (a + s)\,I_{r-} + \frac{I_{r-}}{r} - a\,E - \frac{s}{6}\,I \tag{29}$$

$$\frac{1}{r}\,\frac{d}{d\theta}\,(I_{\theta+}) = -\,(a + s)\,I_{\theta+} + a\,E + \frac{s}{6}\,I \tag{30}$$

$$\frac{1}{r}\,\frac{d}{d\theta}\,(I_{\theta-}) = (a + s)\,I_{\theta-} - a\,E - \frac{s}{6}\,I \tag{31}$$

---

[6] Hamaker, H. C., "Radiation and Heat Conduction in Light-Scattering Material", Philips Research Report, Vol. 2, pp 55-67, 1947.

[7] Patankar, S. V., and D. B. Spalding, "A Computer Model for Three-Dimensional Flow in Furnaces", Fourteenth Symposium (International) on Combustion, The Combustion Institute, 1973.

[8] Siddall, R. G., "Flux Methods for the Analysis of Radiant Heat Transfer", Paper presented at the Fourth Symposium on Flames and Industry, 1972.

where I_{x+}, I_{r+}, and $I_{\theta+}$ are the fluxes along the positive directions of axial, radial and circumferential directions, respectively; I_{x-}, I_{r-}, and $I_{\theta-}$ are the corresponding fluxes along the negative directions.

a = absorption coefficient defined as radiation absorbed per unit length

s = scattering coefficient defined as radiation scattered per unit length

E = black body emissive power = σT^4

where σ is the Stefan-Boltzman constant

$$I = I_{x+} + I_{x-} + I_{r+} + I_{r-} + I_{\theta+} + I_{\theta-}$$

With the composite-fluxes R^x, R^r and R^z defined as:

$$R^x = \frac{1}{2}(I_{x+} + I_{x-})$$
$$R^r = \frac{1}{2}(I_{r+} + I_{r-})$$
$$R^z = \frac{1}{2}(I_{\theta+} + I_{\theta-})$$

one can reduce the six first-order flux equations into the following three second-order equations:

$$\frac{d}{dx}\left(\frac{1}{a+s}\frac{dR^x}{dx}\right) = a\,(R^x - E) + \frac{s}{3}\,(2R^x - R^r - R^z) \tag{32}$$

$$\frac{1}{r}\frac{d}{dr}\left(\frac{r}{a + s + \frac{1}{r}}\frac{dR^r}{dr}\right) = a\,(R^r - E) + \frac{s}{3}\,(2R^r - R^x - R^z) \tag{33}$$

$$\frac{1}{r}\frac{d}{d\theta}\left(\frac{1}{a+s}\frac{dR^z}{\gamma d\theta}\right) = a\,(R^z - E) + \frac{s}{3}\,(2R^z - R^x - R^r) \tag{34}$$

Once R^x, R^r, and R^z are known, the net radiation fluxes in the axial, radial, and circumferential directions, Q^x, Q^r, and Q^z respectively, are given by:

$$\begin{aligned} Q^x &= I_{x+} - I_{x-} \\ &= -\frac{2}{a+s}\,\frac{dR^x}{dx} \end{aligned} \tag{35}$$

$$\begin{aligned} Q^r &= I_{r+} - I_{r-} \\ &= -\frac{2}{a+s+\frac{1}{r}}\,\frac{dR^r}{dr} \end{aligned} \tag{36}$$

$$\begin{aligned} Q^z &= I_{\theta+} - I_{\theta-} \\ &= \frac{2}{a+s}\,\frac{1}{r}\,\frac{dR^z}{d\theta} \end{aligned} \tag{37}$$

The contribution of R^x, R^r, and R^z to the source terms of specific enthalpy, Equation 12, is given by:

$$\begin{aligned} (S_h)_{radiation} = 2a\,[&(R^x - E) + \\ &(R^r - E) + \\ &(R^z - E)] \end{aligned} \tag{38}$$

Since information on the variations of a and s (with other quantities such as concentrations of CO, H_2O, CO and soot particles) is often scarce and unprecise, they have been assumed to be uniform. However, variable values of a and s can be incorporated in the program with minor modifications.

5. Spray Combustion.

It is very important to predict aerodynamic interaction between evaporating/burning sprays and flow field insofar as combustion efficiency, pattern factor, stability, liner-wall temperature levels and gradients, smoke and gaseous emissions formation are concerned. For example, the presence of smaller droplets influence flame stabilization as they provide the main source of heat in the recirculation zone. Larger droplets, however, escape the recirculation zone and are mainly responsible for the smoke formation. Measured data by McCreath and Chigier[9] showed that droplets with initial sizes less than 50 microns were evaporated in the recirculation zone. The smaller droplets were influenced greatly by the recirculation zone velocity field, whereas up to 70 percent of the bigger droplets in the 100-200 microns range escaped the recirculation zone. Their trajectory was not influenced by the flow-field velocity distribution. The flow-field influence on evaporation and trajectory of medium-size droplets, between 50 and 100 microns, was moderate.

Combustion characteristics of liquid droplets burning individually are significantly different from those burning collectively in a spray. For example, Beer and his associates[10] showed that the burning-rate constant of monosized droplet arrays was about half that of single droplets. There was also significant reduction[10,11] in drag coefficient, C_D, as compared to that of a

[9]McCreath, C. G. and N. A. Chigier, "Liquid Spray Burning in the Wake of a Stabilizer Disc", Fourteenth Symposium (International) on Combustion, The Combustion Institute (1973).

[10]Nuruzzaman, A. S. M., A. B. Hedley, and J. M. Beer, "Combustion of Monosized Droplet Streams in Self-Supporting Flames", Thirteenth Symposium (International) on Combustion, The Combustion Institute (1971).

[11]Chigier, N. A., et. al, "Dynamics of Droplets in Burning and Isothermal Sprays", Combustion and Flame, V23 (1974).

nonreactive sphere. On the other hand, Natarajan[12] showed that C_D of a burning droplet should be calculated for a nonreacting sphere at the mean properties and initial diameter.

The quasi-steady droplet combustion theory with spherical symmetry predicts the burning rate constant K to be independent of the surrounding gas pressure, where $K = -\frac{d}{dt} d_L^2$, and d_L is the liquid-droplet diameter. However, it has been found experimentally[13] that K increases with an increase in pressure. Raghunandan and Mukunda[14] critically evaluated the quasi-steady approximation, variable gas phase properties and incomplete combustion as related to predictions of burning-rate constant, the flame-to-diameter ratio and the flame temperature. The liquid-phase unsteadiness lasts for about 20-25 percent of the total burning time. It was shown by the authors that a good correlation with the burning rate data could be obtained by taking thermal conductivity and C_D as a function of concentration and temperature.

A majority of the reported work has been concerned with combustion of single component hydrocarbon fuels. Limited work has been reported, such as Reference 15, for combustion of multi-component fuel droplets; but, these approaches became quite complicated for predicting spray combustion of complex fuels like jet aviation fuels.

---

[12] Natarajan, R., "Experimental Drag Coefficients for Evaporating and Burning Drops at Elevated Pressures", Combustion and Flame, V20 (1973).

[13] Rush, J. H., and H. Krier, "Burning of Fuel Droplets at Pressures Greater than Atmospheric", Combustion and Flame V22 (1974).

[14] Raghunandan, B. N., and H. S. Mukunda, "The Problem of Liquid Droplet Combustion - Reexamination", Combustion and Flame V30 (1977).

[15] Shyu, R. R., C. S. Chen, G. O. Gondie and M. M. Elwakil, "Multi-Component Heavy Fuel Drop Histories in a High Temperature Flow Field", Fuel, V51 (1972).

Figure 4 pictorially presents the approach that has been used for spray combustion in the present program. The spray cone is divided into a number of sections or rays. Each ray has a particular x, y, and z direction associated with it, depending on the orientation of the fuel nozzle in the combustor and the spray cone angle.

The initial conditions for each droplet are that they have a velocity as specified by the program user and a direction corresponding to the particular ray in question. The total fuel-flow rate is currently divided equally among the rays, although it would be easily possible to do otherwise. For each ray and for each droplet size group, of which five are assumed, the droplet trajectories are calculated from a force balance assuming the drag on the droplet is for that of a sphere. Heat transfer to the droplet is calculated using the coefficient given in Equation 39.

$$h = 2\,\frac{K}{D}\,(1+0.3\,Pr^{\frac{1}{3}}Re^{\frac{1}{2}})\,\left(\frac{J}{m^2\text{-}K}\right) \qquad (39)$$

where k is the thermal conductivity of fuel vapor, Re is Reynolds number based on relative velocity, and D is the droplet diameter. Until the droplet reaches the boiling temperature, no evaporation is assumed to occur; however, once reached, the evaporation rate is obtained from the burning rate constant k. Where:

$$k_o = \frac{d}{dt}(D^2)$$

$$k_o = \frac{8}{\rho_f}\frac{1}{CP_1}\ln(1+B)$$

$$B = \text{mass transfer No.} = \frac{1}{L_{vap}}\left[m_{ox}\,\frac{Hc}{i} + C_{p_1}\,(T_\infty - T_\beta)\right]$$

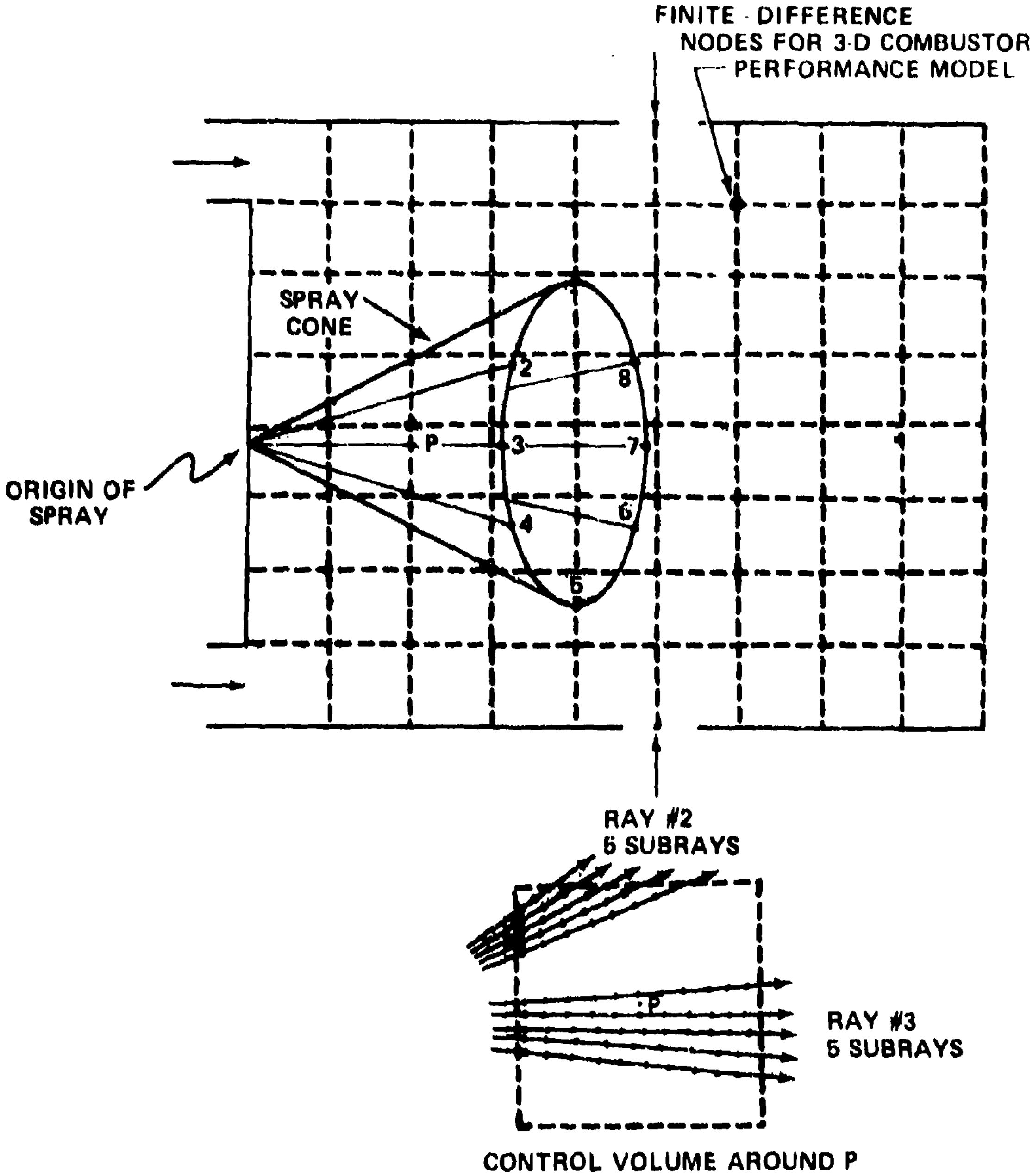


Figure 4. Schematic of Spray in Combustor Flow Field.

H_c = Heat of combustion

i = Stoichiometric O_2-fuel mass ratio

L_{vap} = Latent heat of vaporization

ρ_f = Liquid fuel density

λ_1 and (CP_1) the thermal conductivity and specific heat inside the flame zone, are assumed to be

$$\lambda_1 = 0.4\lambda_f + 0.6\ \lambda_{AIR}$$

$$CP_1 = CP_f$$

and are evaluated at the average of the boiling and flame temperatures. These calculations are performed explicitly, with care taken that the time step is sufficiently small, until at least 99 percent of the fuel has evaporated.

The above procedure requires knowledge of the fuel and air properties. The particular values used in the current program are listed below.

a. <u>Droplet-Size Distribution</u>.

Group	Vol. % of Spray	Size Ratio (D/SMD)
1	0-20	0.6
2	20-40	0.9
3	40-60	1.2
4	60-80	1.5
5	80-100	2.1

b. Liquid-Fuel Density (ρ_f).

$$\rho_f = 1000[PR_{60} + 0.208 - 0.00072\ T_f]\ \frac{KG}{m^3}$$

$$PR_{60} = \frac{1.076}{1 + \frac{1.076}{0.775} - 1\ (1 - 0.67F)}\ \text{for JP4}$$

PR_{60} = Specific gravity of residue at 60°F

F = Fraction evaporated

T_f = Fuel temperature

c. Specific Heat of Liquid Fuel (CP_f).

$$CP_f = 840.5 + 4.1372\ T_f\ (J/KG - °K)$$

d. Molecular Weight of Fuel Vapor.

Interpolated from table below,

F	MW(JP4)
0	93.26
0.1	114.60
0.3	126.61
0.5	138.16
0.7	150.59
0.9	173.21
1.0	204.76

e. Thermal Conductivity of Fuel Vapor (λ_f).

$$\lambda_f = 1.729\ (A+BT_f)\ (J/M-°K-Sec)$$

where A and B are from the following list:

MW_{fuel}	A	B
50	-6.362E-3	53.5E-6
100	-6.358E-3	49.1E-6
150	-6.284E-3	46.6E-6
300	-6.010E-3	42.3E-6

f. Specific Heat of Fuel Vapor (CP_{f_v}).

$$CP_{f_v} = 4183.3\ (0.153 + 0.00081T_f)\ \left(\frac{J}{KG-°K}\right)$$

g. Latent Heat of Vaporization (L_{vap}).

$$L_{vap} = 30676.6\ (1092.88 - 1.8T_f)^{.39}\quad (J/KG)$$

h. Boiling Temperature of Fuel (T_B).

$$T_B = A\ \ell n\ P_v + B\ (°K)$$

where P_v is vapor pressure in pascals, A and B are from the following list:

% Evaporated	A	B
0	41.026	-114.000
10	30.857	41.574
30	27.348	96.534
50	23.997	146.567

The spray calculation procedure is briefly described in the following paragraph. Referring to Figure 4, the analysis is done for each of the rays selected and their subrays. Details are given for the control volume around a point P, where it is shown for two typical rays identified as Ray No. 2 and Ray No. 3. With each of these rays there might be five subrays, or less, depending upon the location of point P, initial droplet sizes, and the properties of the field through which the individual drops have traveled. Depending upon the direction of the ray and the

finite-difference nodal volume, calculations for evaporation/burning are done for a number of subgrid points. The droplets are allowed to exchange mass, momentum, and energy with the surrounding gas phase. The net amount of mass, energy, and momentum received by the node P is the sum total of all droplets passing through the control volume of P.

6. Calculation of Gas Temperature.

With the specific enthalpy and chemical species known, the gas temperature is calculated as follows: The specific enthalpy h is the summation of the enthalpies of individual species, i.e.,

$$h = \sum_i m_i h_i$$

$$\sum_i m_i \left[h_{i,o} + \int_{T_o}^{T} C_{pi}(T)\, dT\right]$$

$$= \sum_i m_i \left[h_{i,o} + \int_{T_o}^{T^*} C_{pi}(T)dT + \int_{T^*}^{T} C_{pi}(T)dT\right]$$

Thus, giving

$$h = \sum_i m_i \left[h_i(T^*) + C_{pi}(T^*)(T-T^*)\right] \qquad (47)$$

where m_i, h_i, h_{io}, C_{p_i}, T^*, and T are species mass fraction, specific enthalpy, heat of formation at a reference temperature T_o, isobaric specific heat, gas temperature of the previous iteration, and the unknown gas temperature, respectively.

Therefore, from Equation 47 one obtains the following expression for the gas temperature T:

$$T = T^* + \left[\frac{h - \sum_i m_i \; h_i(T^*)}{\sum_i m_i \; C_{pi}(T^*)}\right] \qquad (48)$$

The variation of C_p as a function of temperature is taken as a fourth-order polynomial of temperature as given in Reference 16.

7. Finite-Difference Solution of the Equations.

The numerical solution of the nonlinear, coupled, partial differential equations can be obtained by using finite-difference methods. A numerical solution of the hydrodynamic equations can be obtained by two methods. The earlier approach employed for 2-D flows was the so-called streamline-vorticity method[3]. Here pressure is replaced from the momentum equations by differentiation. Stream function (ψ) and vorticity (ω) replace the velocity components and the pressure, thus requiring solution of only two instead of three variables: namely, u, v, and p. The equations were solved by a point-by-point successive-substitution procedure. Since ψ and ω are linked at the boundaries by way of the no-slip condition, the ω boundary specification could be done a number of ways leading to considerably different false diffusion levels as recently evaluated by de Vahl, Davis, and Mallinson[17]. In addition, problems were encountered in obtaining fully converging solutions with nonuniform grid spacing. Since 1973, AiResearch has used a pressure-velocity (primitive variable) solution approach, which has the following three advantages over the ψ - ω method:

- It permits computation of variable density flows where ρ depends upon pressure and temperature.

---

[16] Gordon, S., and B. J. McBride, "Computer Program for Calculation of Complex Chemical Equilibrium Compositions, Rocket Performance, Incident and Reflected Shocks and Chapman-Jouguet Detonations", NASA SP-273 (1971).

[17] de Vahl, Davis, and G. D. Mallison, "An Evaluation of Upwind and Central Difference Approximations by a Study of Recirculating Flow", Computers and Fluids (1976).

- It allows unsteady flows to be calculated as easily as steady ones.

- It works for 3-D flows as well as 2-D flows, whereas the $\psi - \omega$ method cannot be easily extended.

Many primitive variable solution methods have been put forward by different researchers[18]. They vary enormously in complexity, ease of use, efficiency, and applicability. The 3-D combustor performance code is based on the well-tried SIMPLE (Semi-Implicit Method for Pressure-Linked Equations) algorithm of Patankar and Spalding as described in Reference 19. The features of the computer model include:

- Solution of sufficiently general single form differential equations

- Provision for use with different physical models

- Use of pressure and velocities as the main hydrodynamic variables

- Use of the pressure correction technique

- Provision of two coordinate (plane and axisymmetric) systems

- Use of nonuniformly spaced grids

---

[18]Anon., "Proceedings of the Third AIAA Computational Fluid Dynamics Conference", Albuquerque, New Mexico, June 27-28, 1977.

[19]Patankar, S. V., "Numerical Prediction of Three-Dimensional Flows", in Studies in Convection: Theory, Measurement and Application, Volume 1, Edited by B. E. Launder, Academic Press, 1975.

- Use of staggered grid with attendant minimum truncation errors

- Derivation of finite-difference equations by integrating the differential equations over finite control volumes and thus ensuring mathematical compatibility between the finite difference and the original differential-equation formulations

- Efficient line-by-line tri-diagonal matrix solution of the difference equations

- Unconditional convergence for all Reynolds numbers

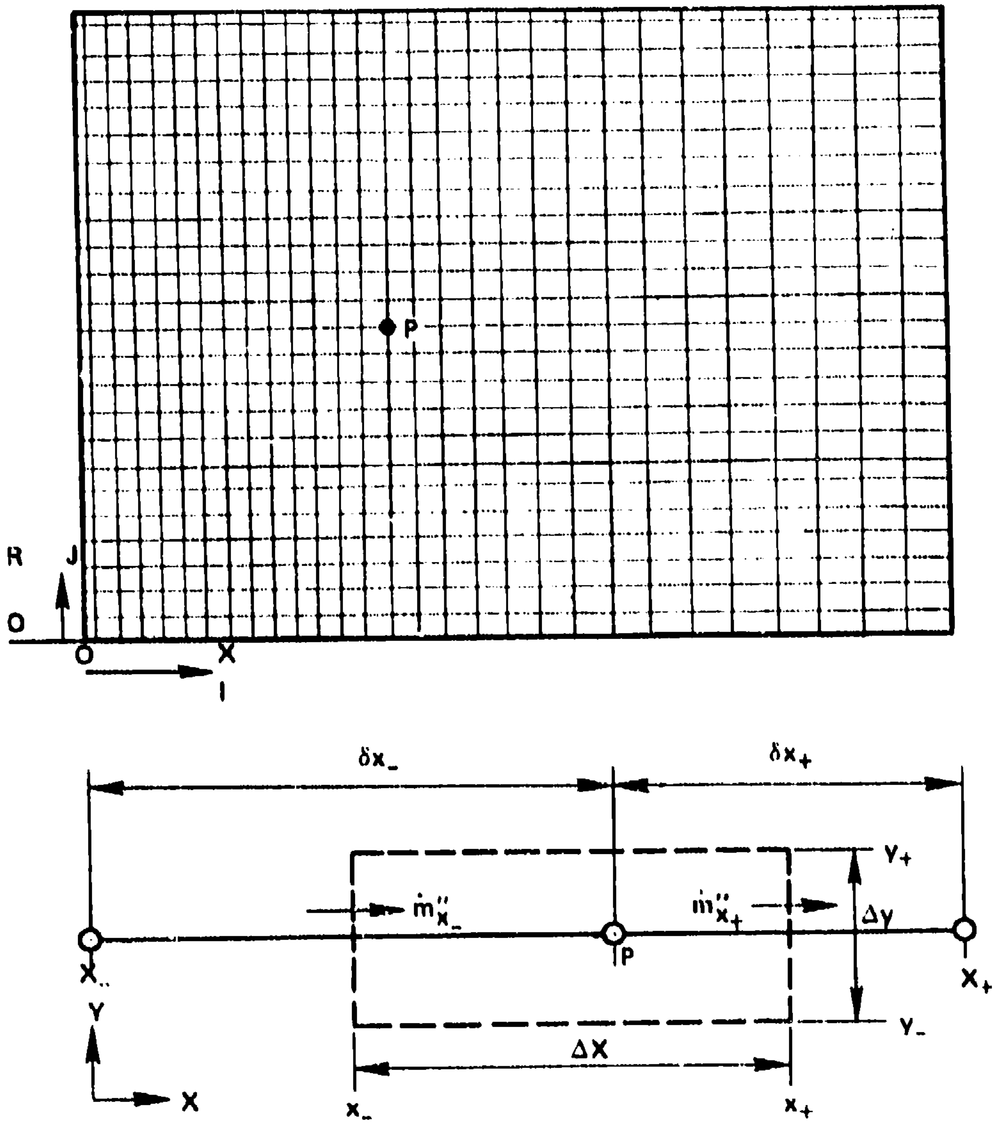
- Provision for under-relaxation

A typical grid node spacing is shown in Figure 5. Finite-difference equations for a node are obtained by integrating the differential equations over a control volume enclosing a grid node. For evaluating the convection and diffusion fluxes through a control volume face, a linear variation (in the direction normal to the face) of the flow properties is assumed. For other purposes, a step-wise variation with discontinuities at control-volume boundaries is assumed. Net rate of flow of ϕ into the control volume around a node P (Figure 5) by convection and diffusion in the x-direction is

$$[T_{X-} + (1 - f_{X-}) L_{X-}] \phi_{X-} + [T_{X+} - f_{X+} L_{X+}] \phi_{X+}$$
$$- [T_{X-} - f_{X-} L_{X-} + T_{X+} + (1 - f_{X+}) L_{X+}] \phi_P$$

where

$$\begin{aligned} T_X &= \Gamma_{eff,\phi} A_X/\delta_X \\ L_X &= \dot{m}_X''/A_X \\ A_X &= 0.5\ (r_+ + r_-)\ \Delta Y \end{aligned} \qquad (49)$$



$$f_{x_-} = \frac{\overline{X_- \, x_-}}{\overline{X_- \, P}} \qquad f_{x_+} = \frac{\overline{P \, x_+}}{\overline{P \, X_+}}$$

Figure 5. Typical Grid Spacing and Control Value Around a Point P.

Defining $\iiint S_\phi V = S_u + S_p \phi_p$, the one-dimensional transport equation for the variable ϕ becomes

$$[T_{X-} + (1 - f_{X-}) L_{X-} + T_{X+} - f_{X+} L_{X+} - S_p] \phi_p$$

$$= [T_{X-} + (1 - f_{X-}) L_{X-}] \phi_{X-} + [T_{X+} - f_{X+} L_{X+}] \phi_{X+} + S_u$$

The above equation was derived based on reasonable assumptions. However, the linear-profile assumption becomes unacceptable when $f_{X+}L_{X+}$ is large compared with T_{X+} because the weighting factor $(T_{X+} - f_{X+} L_{X+})$ then becomes negative, implying an unrealistic physical process through which raising the value of ϕ_{X+} could lower the value of ϕ_p. Therefore, it is assumed that if the convective flow rates (L) are large compared to the diffusion coefficients (T), the diffusion across the control-volume face is zero and the value of ϕ convection is equal to the value at the node on the upwind side of the face. With this assumption, the coefficient $T_{X+} - f_{X+} L_{X+}$ is replaced by $T^*_{X+} - f_{X+} L_{X+}$ where

$$T^*_{X+} = [T_{X+}, - (1 - f_{X+}) L_{X+}, f_{X+} L_{X+}] \qquad (50)$$

Here $[a_1, a_2, a_3]$ stands for the largest of the three quantities a_1, a_2, and a_3.

The final finite-difference equation is reduced to

$$A_p\phi_p = A_{X+}\phi_{X+} + A_{X-}\phi_{X-} + A_{Y+}\phi_{Y+} + A_{Y-}\phi_{Y-} + A_{Z+}\phi_{Z+} + A_{Z-}\phi_{Z-} + S_U \qquad (51)$$

The solution of the above equation is obtained by line-by-line relaxation using an efficient tri-diagonal matrix algorithm. By this method, for an x-y plane, a traverse along one direction, say the X-direction, is made with old values for the y-direction nodes. Using this solution as the best estimate, the y-direction is then traversed. The same procedure is repeated for other x-y planes.

8. Boundary Conditions.

The specification of the boundary conditions is done in a number of ways depending upon the problem. For the left inlet boundaries, velocity, density, and turbulence profiles are either experimentally known or estimated. The program can handle any specified profiles. For boundaries of the second kind, where gradients and not the values of the variables are specified, the program uses one of the following two approaches. In the first approach, the boundary value is guessed and continually updated so as to satisfy the given gradient condition. The second approach breaks the link through the boundary to all adjoining external control volumes by first arranging for the finite-difference coefficient connecting the boundary node to an internal node to be zero, and then inserting the correct flux at the boundary as a false source of diffusion and/or convection for that internal node.

At the symmetry plane, the convection and diffusion fluxes are zero. Therefore, the convection coefficient C_{y-} and the exchange coefficient (Γ_{eff}) are made zero at the axis of symmetry. For the exit plane, information about some of the variables is not available. However, since it is the process occurring in the calculation domain that decides values of the variables which the outgoing fluid will carry, there is no need for information at such boundaries. These boundaries are simply treated by making the boundary Γ_{eff} equal to zero. The cyclic boundary conditions are used for the circumferential direction.

The near-wall region is given a special treatment in the program. Since the expression for Γ_{eff} is accurate for turbulent flows only, a means is provided for the inclusion of the correct shear stresses and other fluxes at the wall. Therefore, the nodes next to the wall are assigned the following values as per an empirical wall law:

$$y^+ \leq 11.5 \qquad \Gamma_{\phi,wall} = \frac{\mu}{\sigma_\phi}$$

$$y^+ > 11.5 \qquad \Gamma_{\phi,wall} = \frac{\mu}{\sigma_\phi} \frac{y^+}{\frac{1}{\kappa}\ln(9y^+) + P_\phi} \tag{52}$$

$$y^+ = \rho\, k^{\frac{1}{2}}\, C_D^{\frac{1}{4}}\, \frac{\delta}{\mu}$$

$$P_\phi = 9.0 \left(\frac{\sigma}{\sigma_{eff}} - 1\right) \left(\frac{\sigma}{\sigma_{eff}}\right)^{-\frac{1}{4}}$$

Where δ is the normal distance of the wall from the first interior adjacent node. The kinetic energy of turbulence has small diffusion near the wall; hence, Γ_{wall} for k is set equal to zero. Instead of computing Γ_{wall} for ϵ, it is calculated for the near-wall node by assuming a linear variation of the length scale giving the following expression:

$$\epsilon = C_D^{3/4}\, k^{3/2} / (\kappa\delta)$$

<u>LINER COOLING MODEL</u>

In order to design a durable combustor with conventional materials, the liner-wall temperature levels and gradients must be controlled. Consequently, it is imperative to have a calculation procedure that can be universally used for predicting liner wall temperatures. The wall temperature at a point P in a combustor liner (shown schematically in Figure 6) is determined by energy balance on a control volume around P, i.e.,

$$C_H + R_H = C_C + R_C$$

where C and R denote the heat transfer rate by convection and radiation, respectively. The subscripts H and C correspond to the hot side and cold side of the liner, respectively.

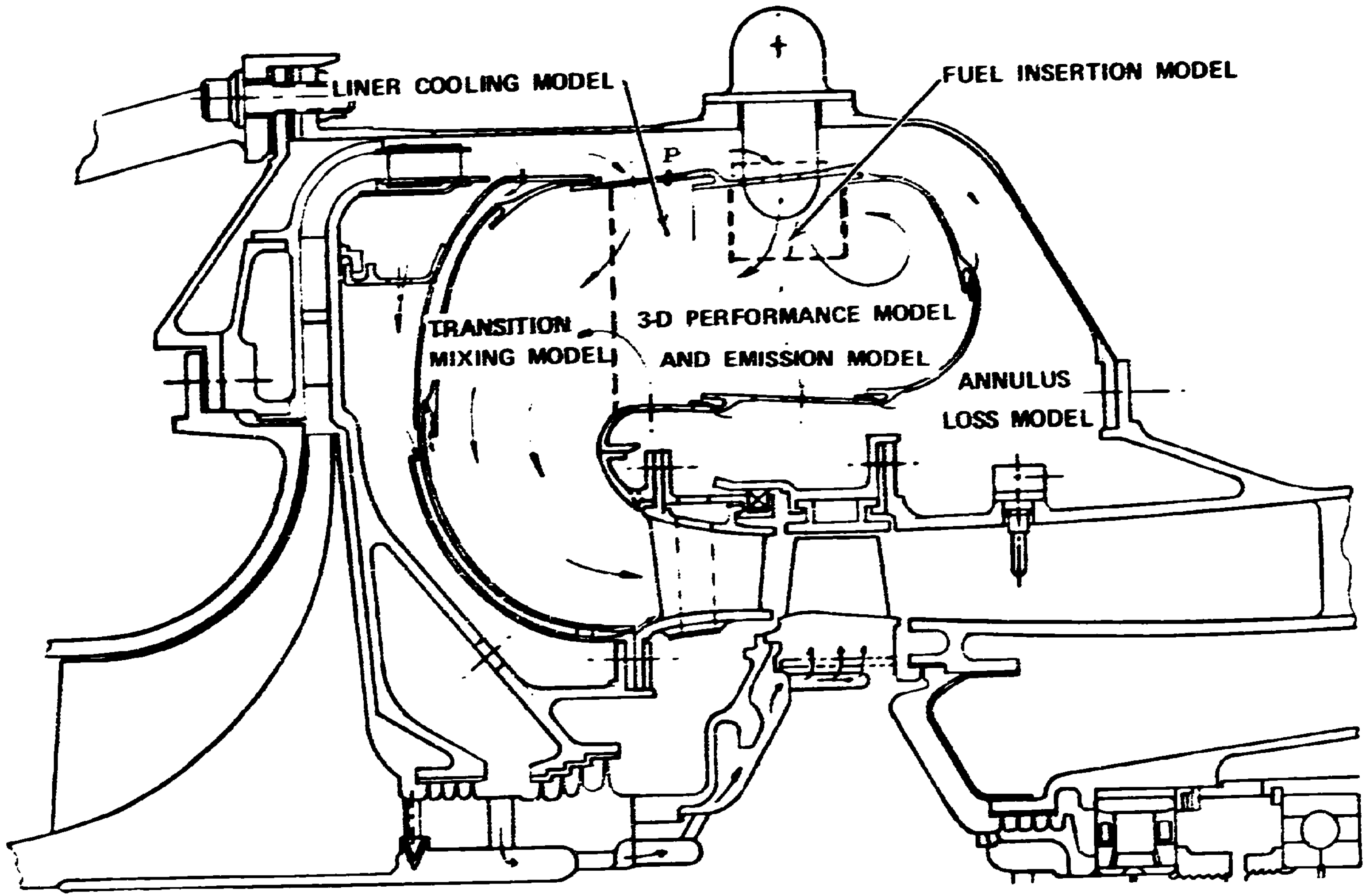


Figure 6. A Schematic of Reverse-Flow Annular Combustor and Application of Analytical Models.

A 2-D parabolic program is used to compute the hot-side convection and radiation heat transfer, the marching direction being x. The following expressions are used for calculating the cold-side heat-transfer rate.

$$C_C = 0.0268(C_P\ G)_{an}\ R_{ex}^{-0.2}\ (T_W - T_{an}) \tag{54}$$

$$R_C = \sigma \left[\frac{1}{\frac{1}{\varepsilon_\omega} + \frac{D_L}{D_P}\left(\frac{1}{\varepsilon_P} - 1\right)} \right] (T_W{}^4 - T_{an}{}^4) \tag{55}$$

where C_{Pan}, G_{an}, and T_{an} are annulus air specific heat, mass velocity, and temperature, respectively. The length Reynolds number is based upon x downstream from the cooling-slot metering orifices. ϵ_W and ϵ_P are the liner-wall and the plenum-wall emissitivites; D_L and D_P are the diameters of the liner and plenum, respectively. σ and T_W are the Stefan-Boltzman constant and the liner-wall temperature, respectively.

One major advantage of using algebraic expressions for the cold-side heat-transfer rates is that the appropriate expressions can be used for advanced cooling schemes that increase the heat-transfer rate from the cold side. Consequently, the cooling schemes, such as multiple impingement, extended-surface geometries, and chemically-etched surfaces, can be predicted by using the liner cooling model developed in this program.

Since a 2-D calculation procedure is used for calculating the hot-side heat-transfer rates, the model is strictly applicable to either uncooled liners or the liner walls protected by cooling films. The user will need to make approximations in predicting wall temperatures downstream from discrete radial jets such as the primary and secondary jets.

The 2-D parabolic program solves the governing equations for the following variables:

- Streamwise velocity and swirl velocity
- Turbulence kinetic energy and dissipation model of Jones and Launder[20].
- Specific enthalpy
- Unburned fuel, CO, and total fuel appropriate to the two-step kinetic scheme.
- Composite-radiation flux for the two-flux radiation model.
- Five-droplet trajectories

The governing equations, as reduced from the set of equations presented in paragraph B for parabolic flows, are transformed to the following generalized form of transport equations for the von Mises coordinate system[21].

$$\frac{\partial \phi_j}{\partial x} + (a + b\omega)\frac{d\phi_j}{d\omega} = \frac{\partial}{\partial \omega}\left(c\,\frac{\partial \phi_j}{\partial \omega}\right) + d_j \qquad (56)$$

where

$$a = r_I\,\dot{m}''_I/(\Psi_E - \Psi_I) \qquad (57)$$

$$b = (r_E\dot{m}''_E - r_I\dot{m}''_I)/(\Psi_E - \Psi_I) \qquad (58)$$

$$c = \frac{r^2\rho u\,\mu_{eff}}{(\Psi_E - \Psi_I)^2\,\sigma_{j,eff}} \qquad (59)$$

$$\omega = (\Psi - \Psi_I)/(\Psi_E - \Psi_I) \qquad (60)$$

---

[20] Jones, W. P., and B. E. Launder, "The Calculation of Low-Reynolds Number Phenomena with a Two-Equation Model of Turbulence", ASME Paper 72-HT-20, 1971.

[21] Patankar, S. V., and D. B. Spalding, "Heat and Mass Transfer in Boundary Layers", Intertext Books, London; 1970.

Here ϕ_j is a generalized variable, and d_j contains the source/sinks and the other terms in the governing equation that do not fit in the convection and diffusion terms presented in Equation 56. ψ, r, and $\dot{m}''$ denote streamline, radius, and entrainment rate across the boundaries $\psi = \psi_I$ and $\psi = \psi_E$. The subscripts I and E refer to the inner and outer (external) boundaries of the domain of interest.

The numerical scheme used is a variant of the efficient numerics of Patankar and Spalding as described in Reference 21. A brief description of how the model is used for predicting liner-wall temperatures is given in the following paragraphs.

Consider a typical combustor liner and its predicted isothermal lines for an x-y plane; e.g., in line with primary jets, such as shown in Figure 7. The 3-D combustor-performance model predicted a reverse flow region near the dome, as shown by broken lines. This particular combustor has three cooling slots on the OD liner wall and four cooling slots on the ID wall. The wall-cooling model is used for predicting both inner- and outer-liner wall temperature with initial conditions for the three stations shown, defined by the combustor-performance model. The number of x-y planes to be solved depends upon a particular combustion system. If the predicted combustor internal flow is highly three-dimensional, then one may have to solve as many planes as the number of θ-nodes used in the 3-D computation. However, as the flow field approaches a two-dimensional approximation, one need not analyze more than a few x-y planes to obtain an accurate wall-temperature prediction.

Since the present wall-cooling model is a two-dimensional model, it cannot analyze wall regions near primary, intermediate, and dilution orifices. Consequently, it is advisable to restart the model for each panel with initial conditions as given by the combustor-performance model. Care should be taken in analyzing

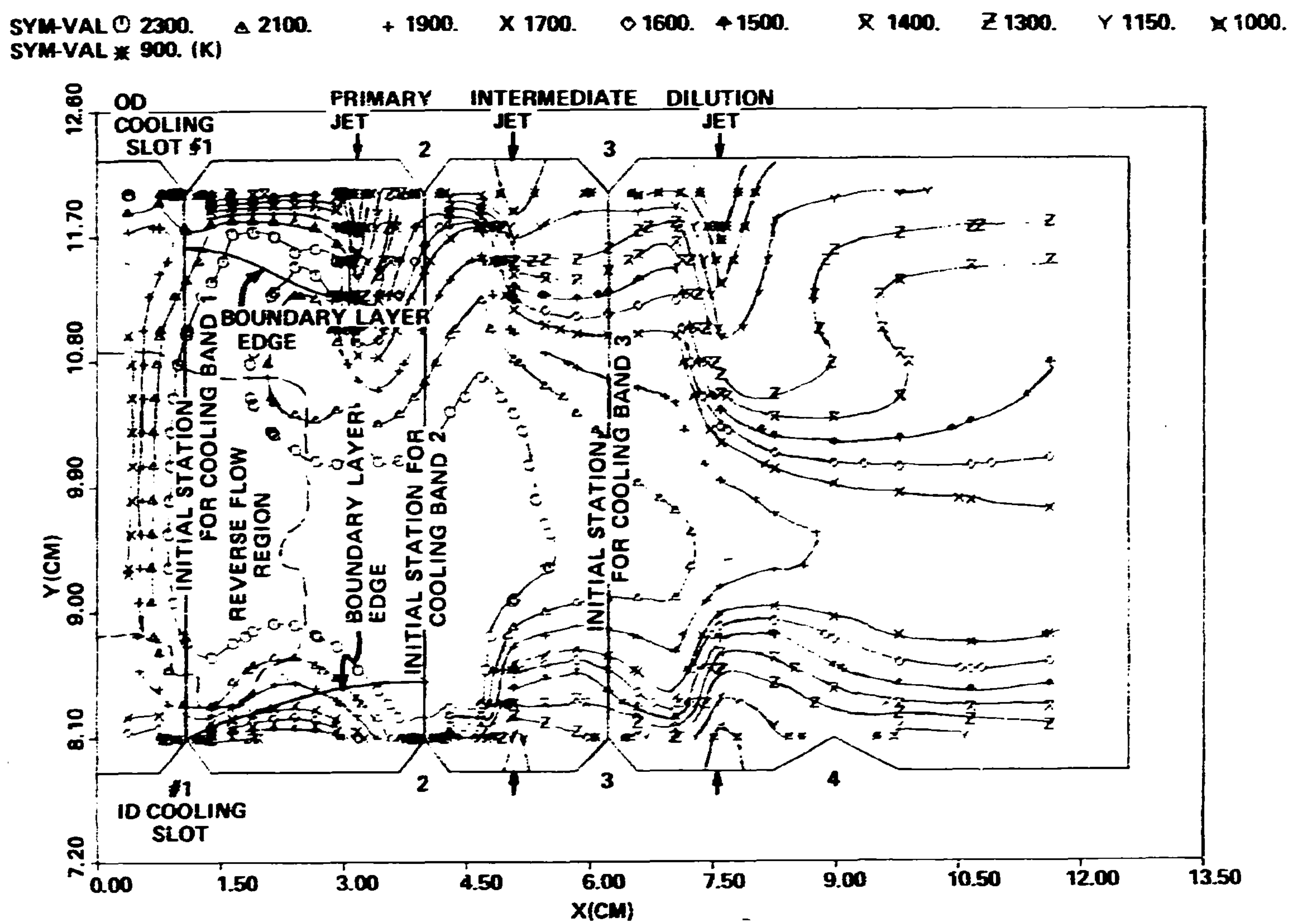


Figure 7. Typical Isothermal Plots of an Annular Combustor Along X-Y Plane In Line With Primary Jet.

the primary panel because of the presence of reverse-flow region. There are two possible approaches for analyzing this section. The first approach, the marching region lies between the liner walls and u > 0 with exchange rate specified for u > 0 line. In the second approach, one can define a boundary edge for which the edge conditions for dependent variables, including radiation flux, are defined based upon the combustor performance predictions. Then the wall-cooling model is run separately for the inner and outer primary panels.

In order to get more accurate wall temperature predictions, it is imperative to know the precise cooling slot exit conditions. In addition, one must accurately predict the effect of the splash-plate thickness on initial mixing between the cold-stream and main-combustion gases. The 3-D elliptic code can be used with minor modifications to predict the development of the jets exiting from the cooling-slot metering orifices. The effect of liner-pressure drop, orifice size and spacing, slot-lip length, and height on the slot-exit profiles can be analytically predicted. The 3-D elliptic code can also be used to predict the effect of the lip thickness on the initial mixing between hot and cold streams.

TRANSITION-LINER MIXING MODEL

The overall length of a gas turbine engine that employs a centrifugal compressor as the last stage of compression can be minimized by using a reverse-flow combustor. When the engine uses an axial turbine as its high-pressure turbine, a transition liner is needed between the combustor exit and the stator inlet. The transition-liner geometry, as shown in Figure 6, is quite complicated in that combustor exit flow, with mainly axial velocity component flowing from right to left, is bent through a 180-degree turn in order to flow into the turbine stator. The radii of curvature of both the inner- and outer-liner walls vary as a function of distance along the surface.

The flow in a practical transition liner is generally stream wise with little separation. Small regions of separated flows may exist along the ID transition liner surface. But, to insure structural durability of the liner, cooling air is generally injected in these separated areas so that the local liner-temperature levels and gradients are within allowable limits. As burner-exit temperatures increase along with reduction in burner length, cooling-film bands might be used for maintaining transition liner-wall temperature characteristics at an acceptable level.

A significant fraction of the mixing of hot streaks with the cooler combustor gases takes place within the transition liner. With the advent of volume-limited turbopropulsion engines, there would be need to predict performance of the transition liner in regard to exhaust-temperature quality. In addition, the transition-liner-wall temperatures must be determined so as to estimate the liner life. A 2-D transition mixing model was therefore developed for this purpose. The program was adopted from the wall-cooling model described in the Liner Cooling Model paragraph. It solves governing equations for streamwise velocity and swirl velocity, specific enthalpy, turbulence kinetic energy, and dissipation. The effect of curvature on radial pressure gradient is taken into account. However, the pressure elliptic effects due to streamline curvature have been neglected.

GASEOUS EMISSIONS MODEL

Both the combustor-performance model and the wall-cooling model use a simple kinetic scheme in that the combustion process is described by two reaction steps, as given by Equations 18 and 19. Such a scheme is manageable for complex computer codes like the combustor-performance model. In addition, the model predicts both unburned fuel and CO which accounts for most of the combustion inefficiency. Since the engineer is generally interested in

estimating combustion efficiency of a given combustor design, the combustor performance model is adequate for the purpose. However, when there is a need for estimating the NO_x emissions, one should preferably use a detailed kinetic scheme so as to predict intermediate species (such as O, N, and OH) that are considered important for the NO production. A number of calculation procedures exist for estimating the NO_x levels; e.g., those described in References 22 and 23. The approach taken here is explained as follows.

The wall-cooling model was modified to incorporate the following 16-step kinetic scheme involving 11 chemical species.

$$C_XH_Y + \left(\frac{X}{2}+\frac{Y}{4}\right)(O_2 + 3.76\ N_2) \longrightarrow \left(XCO + \frac{Y}{2}\right) H_2O + \left(\frac{X}{2}+\frac{Y}{4}\right)(3.76\ N_2) \tag{61}$$

$$CO + OH \rightleftharpoons CO_2 + H \tag{62}$$

$$CO + O_2 \rightleftharpoons CO_2 + O \tag{63}$$

$$M + CO + O \rightleftharpoons CO_2 + M \tag{64}$$

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \tag{65}$$

$$O_2 + H_2 \rightleftharpoons OH + OH \tag{66}$$

$$OH + H_2 \rightleftharpoons H_2O + H \tag{67}$$

$$O_2 + H \rightleftharpoons OH + O \tag{68}$$

$$O + H_2 \rightleftharpoons OH + H \tag{69}$$

$$O + H_2O \rightleftharpoons OH + OH \tag{70}$$

$$H + H + M \rightleftharpoons H_2 + M \tag{71}$$

$$O + O + M \rightleftharpoons O_2 + M \tag{72}$$

---

[22]Sanborn, J. W., R. S. Reynolds, and H. C. Mongia, "A Quasi-Three-Dimensional Calculation Procedure for Predicting the Performance and Gaseous Emissions of Gas Turbine Combustors", AIAA Paper 76-642, 1976.

[23]Mosier, S. A., and R. Roberts, "Low-Power Turbopropulsion Combustor Exhaust Emissions, Volume 3, Analysis", Technical Report AFAPL-TR-73-36, 1974.

$$O + H + M \rightleftharpoons OH + M \quad (73)$$

$$N + OH \rightleftharpoons NO + H \quad (74)$$

$$N_2 + O \rightleftharpoons NO + N \quad (75)$$

$$O_2 + N \rightleftharpoons NO + O \quad (76)$$

A one-step global reaction is assumed for oxidation of fuel to CO as described by Equation 56. This reaction step is similar to the first reaction of the two-step kinetic scheme used in the combustor-performance model and the wall-cooling model. The reaction step is slightly different from that proposed by Edelmen[24] where his postulation produces H_2 instead of H_2O, assumed here. A set of four reactions are used to describe oxidation of CO. Eight steps are used for reactions involving H_2, O_2 and their dissociation products. Finally, three reaction steps are used for the NO production. Although the program uses the 16-step kinetic scheme, a more extensive kinetic scheme such as that used by Edelman can be incorporated with relative ease.

The fuel-oxidation reaction is controlled by both chemical kinetics and turbulence similar to the scheme used in the two-step kinetic scheme described in paragraph B3. The remaining 15 reaction steps are controlled by chemical kinetics, although the modified eddy-breakup model could be used for these reactions also.

The numerical scheme used in the emission model is slightly different from that used in the wall-cooling model in regard to the way the source term d_j of Equation 56 is calculated for the 11 chemical species. For each marching step

[24] Edelman, R., J. Boccio, and G. Weilerstein, "The Role of Mixing and Kinetics in Combustion Generator NO_x", Paper presented at AICHE Symposium on Control of NO_x Emissions in Direct Combustion Power Sources, 1973.

size ΔX of the parabolic program, d_j for the chemical species is computed by using the following 1-D equation

$$\frac{\partial \phi_j}{\partial x} = d_j^* \tag{77}$$

which is obtained by neglecting the cross-stream convection and diffusion terms of Equation 56. Equation 77 is solved for each of the species by taking a number of steps for the distance ΔX. Typically, 50 steps are used for each ΔX. With the source terms for the species now estimated, Equation 56 is then integrated for each of the species over the distance ΔX. Such a modification results in approximately 70-percent reduction in computation time as compared to the numerical scheme used in the wall-cooling model.

FUEL-INSERTION MODEL

It may be recalled that a spray-combustion model is used in the combustor-performance code. This spray-combustion model includes heating, evaporation, and combustion of the spray, as well as the spray trajectories. The code also allows for the exchange of mass, momentum, and energy between the spray and the gas phase. Since a complete solution of the 3-D combustor-performance model takes a long computation time, on the order of three hours on the Cyber 174, an inexpensive calculation procedure was needed for initial selection of the fuel-nozzle characteristics. In addition, such a procedure would allow approximate evaluation of different nozzle designs in a flow field as computed by the combustor-performance model. A fuel-insertion model was therefore developed for this purpose.

Fuel-droplet evaporation rate and heat-transfer rate of the droplet are calculated according to the Priem-Heidmann model as described briefly in the following paragraphs. Vaporization of the droplet m_f, lbm/sec is given by

$$\dot{m}_f = A_s \; K \; P_{vap} \alpha \tag{78}$$

$$Nu_m = \frac{2 \; r_L K}{\rho_{vap} D} = 2 \; (1 + 0.3 \; S_c^{1/3} \; R_e^{1/2}) \tag{79}$$

$$\alpha = \frac{P_\infty}{P_{vap}} \ln \frac{P_\infty}{P_\infty - P_{vap}} \tag{80}$$

where A_s, K, Nu_m, P_{vap}, r_L, ρ_{vap}, D, S_c, R_e, and P_∞ are droplet-surface area, burning-rate constant, Nusselt number for mass transfer, fuel-vapor pressure, droplet radius, fuel-vapor density, diffusivity, Schmedt number, Reynolds number, and surrounding pressure, respectively.

Similarly, heat-transfer rate to the liquid surface q_v, Btu/sec is given by

$$q_v = A_s \; h \; (T_\infty - T_L) \; Z \tag{81}$$

$$Nu_H = \frac{2hr_L}{k} = 2 \; (1 + 0.3 \; P_r^{1/3} \; R_e^{1/2}) \tag{82}$$

$$Z = \frac{z}{e^z - 1} \tag{83}$$

$$z = m_f \; C_{p,vap}/h \; A_s$$

where h, Nu_H, k, P_r, and $C_{p,vap}$ are heat-transfer coefficient, Nusselt number for heat transfer, thermal conductivity, Prandtl number, and isobaric-heat capacity of fuel vapor, respectively.

As in the spray combustion model of the combustor performance code, the spray is divided into five discrete droplet sizes. The physical and chemical properties of the jet fuels are varied as a function of the fraction evaporated, as described previously in Paragraph B5.

The following expressions for the spray SMD are currently incorporated in the code. These can be easily changed by the user if desired.

1. Simplex Nozzle.

$$SMD = \frac{225 * W_f^{0.205} \left(\frac{\mu}{1.5}\right)^{0.3}}{\Delta P_f^{0.354}} \tag{85}$$

2. Simplex Nozzle with Air Assist.

$$SMD = \frac{196 \sqrt{\frac{\sigma \cdot S}{\rho_a}} (\mu)^{0.095}}{0.438 \left(\frac{W_a}{W_f}\right)^{0.1} V_{aa} \left[0.5 + \left(\frac{V_f}{V_{aa}}\right)^2 - \frac{V_f}{V_{aa}}\right]^{1/2}} \tag{86}$$

3. Duplex Nozzle.

$$SMD = \frac{330 W_f^{0.205} \left(\frac{\mu}{1.5}\right)^{0.3}}{\left[\frac{\Delta P_p W_{fp} + \Delta P_s W_{fs}}{(W_{fp} + W_{fs})}\right]^{0.354}} \tag{87}$$

4. Duplex Nozzle with Air Assist.

$$SMD = \frac{196 \sqrt{\frac{\sigma \cdot S}{\rho_a}} (\mu)^{0.095}}{0.438 \left(\frac{W_a}{W_f}\right)^{0.1} V_{aa} \left[0.5 + \left(\frac{V_f}{V_{aa}}\right)^2 - \left(\frac{V_f}{V_{aa}}\right)\right]^{1/2}} \tag{88}$$

5. Air-Blast Nozzle.

$$SMD = 1.25 \left(\frac{\sigma \rho_f}{D_f}\right)^{1/2} \frac{\left(1+\frac{W_f}{Wa_n}\right)}{V_a \cdot \rho_a} + 0.73 \left(\frac{\nu_f^{\,2}}{\rho_a \sigma}\right)^{0.425} \frac{\left[1 + \left(\frac{W_f}{Wa_n}\right)\right]^2}{D_f^{\,0.575}} \quad (89)$$

where:

W_f = Fuel flow
μ = Fuel viscosity
ν = Fuel kinematic viscosity
ΔP_f = Fuel-pressure drop
σ = Fuel-surface tension
S = Fuel-sheet thickness
ρ_a = Air density
W_a = Air-assist airflow
V_{aa} = Air-assist air velocity
V_f = Fuel velocity
ΔP_p = Primary fuel-pressure drop
ΔP_s = Secondary fuel-pressure drop
W_{fp} = Primary fuel flow
W_{fs} = Secondary fuel flow
ρ_f = Fuel density
D_f = Filming diameter
Wa_n = Air-blast airflow rate

III. DESCRIPTION OF COMPUTER CODES

ANNULUS FLOW MODEL

The annulus-flow model calculates flow conditions around the combustor annulus by solving 1-D fluid-flow equations and provides information regarding annulus axial and tangential velocities, heat transfer from the liner wall, flow rates, jet velocities, jet angles and discharge coefficients of the various liner orifices, as well as the overall liner-pressure drop. Coding logic is provided so that the user may analyze can, and axial-flow and reverse-flow geometries. In addition, options allow the program to calculate the pressure drop for a given inlet flow rate or inlet flow for a given pressure drop. The program will also calculate either the flow through a specified orifice row or the orifice diameters required to pass a specified-flow rate. Finally, a plot, if desired, can be made giving the flow conditions around the combustor annulus and through the liner orifices.

The function of the MAIN program (a computer listing has been provided in Appendix B) is to call subroutine COMANN, which is the main controlling routine, and to perform file manipulations in the case of an axial-flow geometry. For this geometry, one item (usually not known) is the flow split between inner and outer panels. The user inputs essentially two separate cases, one for the OD panel and one for the ID. The program will then iterate on the flow split until the inner- and outer-panel pressure drops are equal. While calculations are being performed on one panel, information about the other is stored on scratch files.

Subroutine COMANN performs the iteration logic and calls the other subroutines as required. Iteration on pressure drop or

flow rate is performed until the calculated flow through the liner orifices agrees to within 0.05 percent of the inlet flow. However, if a solution is not obtained in 20 iterations, the program will stop, as errors in the input or high annulus Mach numbers could make convergence difficult. Of particular importance is the variable RELAX, defined at card C0.31. This is a relaxation parameter used in the convergence logic and has considerable influence on the convergence rate. The simple function provided has worked moderately well for various combustor geometries; however, for complex designs or high annulus mach numbers it is anticipated that the value of RELAX will need to be reduced to obtain a solution.

The names of the remaining subroutines are descriptive of their functions. All data cards are read in subroutine INPUT and then are printed out in subroutine PINPUT. INLET calculates the inlet conditions to the combustor annulus while LENGTH and FLOW perform calculations of annulus flow conditions and orifice flow conditions, respectively. FLOW, in turn, calls JET and DCOEF which calculate the orifice jet velocity and discharge coefficient. Some attention to cards DC.34 to DC.57 in DCOEF is warranted. As there was only qualitative agreement between the measured and calculated discharge coefficients, a constant multiplier was applied to the calculated values. Line printer output is produced in PROUT while the plots are generated in PICTUR and BOXES.

3-D-COMBUSTOR-PERFORMANCE MODEL.

The 3-D performance model is a three-dimensional recirculating-flow program that is capable of analyzing a variety of combustor configurations, including can, can-annular, and annular. The deck solves for the three velocity components, U, V, and W, three species concentrations, including UHC and CO,

turbulence qualities for the K-ϵ viscosity model, and three radiation fluxes. In addition, the use of primitive variables makes modifications to the boundary conditions easy, allowing the user to analyze complex inlet geometries. Also provided is a subroutine for calculating the trajectories and evaporation rates of a fuel-nozzle spray.

Program MAIN (a computer listing has been provided in Appendix C) is divided into two basic sections. Up to card MA.167, the routine is concerned with reading the input data and converting it to the program's internal units which are Systéme International (S.I.). The input sequence is covered in paragraph B of Section IV so only the units will be discussed. Cards MA.7 to MA.11 are used to define seven arrays which convert lengths associated with dimensions and lengths associated with velocity, energy, mass, temperature, pressure, and angles respectively. By proper specification in the data statements, the user may employ those input units that are most convenient. The output units are always S.I. From card MA.168 on, MAIN's function is to call the other various routines in their proper sequence.

Subroutine INITIAL performs some preliminary calculations (AL.10 to AL.155), prints the input data (AL.156 to AL.258), and defines the initial conditions and some of the boundary conditions on the various arrays (AL.259 on). In section AL.48 through AL.78, two arrays, JKIN and IKIN, are defined. They merely contain flags which indicate the locations of mass injection points. Cards AL.261 to AL.272 contain logic for the restart option. If Tape 8 from a previous run is saved and then made available for use during a subsequent run, the program will read the initial and boundary conditions from it.

Subroutine ALLMOD contains several entry points which perform miscellaneous calculations pertaining, usually, to the

boundary nodes where modifications to the standard equation are in order. The cyclic nature of the boundary conditions in the θ or K direction is evident in FMOD as well as limits to the fuel and carbon monoxide mass fractions. VELMOD allows the inlet swirl velocity to be increased gradually over a number of iterations and assures that overall continuity is maintained at the exit plane. DENMOD makes alterations to the density at the boundaries to maintain the correct mass-flow rate. GAMOD specifies the wall viscosity values as calculated by the wall functions. SOMAS is used to initialize an array DIVG which is used later in the program. The largest entry point SOMOD contains logic for modifying the equation coefficients and source terms when cooling slots, walls, and droplet evaporation are present. Each variable has its own section and accounts for transfer with the walls and mass addition from the evaporating fuel. SOMODZ deals only with the Z-direction radiation equation and is in a section alone as the data storage is slightly different for this variable.

Subroutine AUX performs the auxilliary calculations for temperature, density, viscosity, and source terms. Entry DENS uses AU.11 to AU.56 to calculate temperature. Cards AU.52 to AU.56 limit the values calculated in order to account for disassociation and early iteration fluctuations. With known temperature, density is then determined from AU.57 to AU.108. VISCO obtains effective viscosity from turbulent kinetic energy and dissipation and calculates y+ for use by the wall function routine. SOURCE contains all calculations for source terms with the exception of the aforementioned modifications in SOMOD. Again each variable has its own section, with coding that is quite straightforward and requires no explanation.

Subroutine AUXRAD performs the same function as AUX except that it pertains only to the radiation equations.

SPRAY is used to determine the evaporation rate of the fuel-nozzle spray. A large section, from SP.106 to SP.269, deals with locating the droplet, determining free-stream conditions, and handling the situation where the droplet approaches a boundary. Next, various fuel- and free-stream properties are evaluated (to SP.292). The drag forces and time step are then determined and used to obtain new velocities and location. If the droplet is below the boiling temperature, no evaporation occurs (SP.340 to SP.347); but, when the boiling temperature is reached, evaporation rates are calculated, and the appropriate entries to the evaporation array (EVAP) are made. Information concerning momentum changes due to evaporation are also stored in their respective arrays and later (SP.382 to SP.425) on a scratch file for use when the three momentum equations are solved.

The coefficients for each variable are generated and the solution routine called in subroutine STRIDE. First, equations for U, V, and W are handled (ST.117 to ST.632), then the pressure perturbation (P') is obtained (SP.633 to ST.714) and used to correct the velocities (SP.716 to ST.753) so that mass errors are minimized. Then, the remaining variables are solved with the radiation equations having their own special section (ST.915 to ST.937).

STRAD is a subroutine used in the radiation model which performs the same function as STRIDE performed for the other variables.

SOLVE provides a solution to the equations generated in STRIDE. A full three-dimensional solution would be time consuming and would require enormous computer storage. Therefore, an approximate solution is obtained by "sweeping" through the field several times alternately solving along one direction, while holding the values in the other two fixed. The variable ICTDMA

(UV) at S0.36 is used to specify the number of such sweeps. As the program converges, and the variables assume their final values, the solution becomes more and more accurate.

LINER COOLING MODEL

This program is derived from the 2-D parabolic GENMIX program of S.V. Patankar and D.B. Spalding[21]. Modifications have included the addition of a two-equation viscosity model, two-step reaction scheme, two-flux radiation model, plus subroutines for calculating wall temperatures and liquid-fuel-evaporation rates.

The basic geometry for which this program has been geared is continuous inner and outer walls or continuous inner axis of symmetry and outer wall. Other situations may be analyzed provided the proper internal modifications are made to the code.

The MAIN program (a computer listing has been provided in Appendix D) handles several functions, including input, establishment of initial profiles, logic for boundary conditions, calling the additional routines in sequence, and output. The initial section of MAIN (through MA.369) deals with input and initial conditions. Input begins at MA.44 with the case title followed by control indices and grid parameters. More computer storage has been provided than is required for the six species involved in the two-step reaction-scheme, therefore, the extra arrays are zeroed. Various other variables are initialized prior to reading the name list at MA.187. The initial profiles are read from MA.212 to MA.222 and values are assigned to all the arrays from MA.292 to MA.269. The main marching loop (MA.272) begins with the calculation of pressure, temperature, and density (through MA.472). STRIDE(1) called at MA.497 calculates the

[21] Patankar, S. V. and D. B. Spalding.

physical dimension of y from the transformed cross-stream variable ω. The forward step size is next determined along with checks for specified X-locations. The boundary conditions are established between MA.528 and MA.743, and in this deck can be either an inner wall or axis of symmetry and an outer wall. Sections dealing with others are bypassed. The wall temperatures of the inner and outer walls, if required, are determined by the two call statements MA.747 and MA.748, while STRAD (MA.750) is a subroutine used to calculate the radiation flux. Duct geometry and pressure gradient occupy the next section MA.755 to MA.857 and provides two methods for pressure gradient calculation which are selected by IDPDX. When the value is 01, the program uses a guess-correction method, whereas for a value of 02, the program immediately corrects the velocity and pressure fields if the duct area and flow area differ. Entrainment rates are calculated from MA.907 to MA.934 but are not used in any calculations by this code. DROP, a subroutine called at MA.937, calculates the evaporation rates of the liquid-fuel spray. This is followed by STRIDE(2), which performs some preliminary calculations needed prior to solving the equations. The remainder of MAIN is devoted to printout with the exception of STRIDE(3), called at MA.1195 which actually solves the finite difference equations.

Subroutine AUX has two parts; the first (through AU.37) calculates the effective viscosity from the two equation turbulence model, while the second computes the source terms for each equation.

As mentioned above, DROP calculates evaporation rates. Note that the input data for the fuel nozzle is read at AUS.15. With the location of a particular droplet established (AUS.42 to AUS.68), properties of the fuel and free stream are determined (AUS.76 to AUS.94). Some preliminaries are performed before iterative loop AUS.111 to AUS.151 is entered. Calculations are performed until the guessed value of the distance the droplet

travels agrees with the calculated value. With this distance and the droplet velocity known, the time step and evaporation rate can be determined. The proper entries in the evaporation array EVAP are then made at AUS.173 and AUS.190.

STRAD performs all calculations relative to the two-flux radiation model. Modifications to the source terms due to the presence of a wall are made at GA.130 to GA.136. The central difference coefficients are then computed and solved using the standard tri-diagonal algorithm.

WTEMP uses an energy balance on the wall to determine the wall temperature. Cold-side convection, cold-side radiation, hot-side radiation, and hot-side convection are calculated in turn, and a Newton-Raphson iteration procedure is employed to solve the resulting heat-flux equation. The cold-side velocity and temperature are updated at each marching step, accounting for the heat transferred to the annulus.

STRIDE performs the bulk of the numerical calculations and has been documented in literature.

WF is used to evaluate the Couette-flow-equation solutions and to obtain wall shear stress and other transfer data.

PLOTS is a line printer plot routine.

TRANSITION LINER MIXING MODEL

This computer code is derived from the 2-D parabolic GENMIX program of S.V. Patankar and D.B. Spalding. The primary modifications include the ability to have a varying step size across the grid, since, for a given number of marching steps, the distance traveled along the outer-transition liner is considerably greater than along the inner. Other modifications include the addition of K-ϵ viscosity model.

A computer code that could handle all geometrical configurations would be greatly increased in size; therefore, this deck has been tailored to the geometry of a reverse-flow annular-combustor transition liner. Other configurations can be analyzed if the proper modifications are made to the computer code.

The MAIN program (a computer listing has been provided in Appendix E) handles several functions, including input, establishment of initial profiles, logic for boundary conditions, calling additional routines in sequence, and output. The initial section of MAIN, through card MA.255, contains input and data initialization coding. Note that the x and r values of the boundaries are read at cards MA.64 and MA.65, but that the value of Z, the actual marching direction, is computed at MA.74 and MA.77. ISOLVE and IPRNT perform the functions their names suggest, determining which variables are solved for and printed. Various constants are initialized in the next few cards. MA.157 is of some significance since it is here that the name list is read, and finally the various profiles are read in and defined. Starting at MA.256, the main marching loop begins with the calculation of pressure, temperature, and density (MA.293 to MA.315). STRIDE(1), called at MA.345, is a subroutine which extracts the physical cross-stream dimension from the transformed cross-stream variable, ω. The forward step size is calculated in the next section (MA.349 through MA.403), which was necessitated by having a smaller step size at the inner boundary than the outer, plus some checks for specified z-locations. Next, the boundary conditions are assigned (MA.406 to MA. 479), and since they are always walls in the transition liner, only those appropriate sections are entered. The actual duct area is determined in section MA.481 through MA.505, plus the area required by the flow. Should these two not agree, compensation in the pressure gradient for the next marching step will be made. The pressure gradient is calculated between MA.507 and MA.598. Two methods are provided and are selected by IDPDX. When the value is 01, the program uses a guess-correction method (MA.539 through MA.543),

whereas for a value of 02, the program immediately corrects the velocity and pressure fields (MA.521 through MA.536). The pressure gradient across the grid due to radius-of-curvature effects is calculated at MA.579 and incorporated into the axial-pressure gradient at MA.595. Statement MA.645 calls AUXO(0), which calculates the effective viscosity from the K-ϵ model. Since there is no entrainment for the geometry employed, cards MA.646 through MA.670 are bypassed. STRIDE(2), called at MA.673, performs some preliminaries necessary prior to the equation solution. The rest of MAIN is devoted to outputs of various types with the exception being MA.902 where STRIDE(3) is called, solving the equations for that marching step.

Subroutine AUX performs two functions; it calculates effective viscosity (up to AU.37) and the source terms for the equations (AU.38 on). Subroutine STRIDE performs the bulk of the numerical calculations and has been heavily documented in literature. Subroutine WF is used to evaluate the Couette-layer-equation solutions near a wall, to extract shear stress and other transfer data needed in the solution of the equations, and finally PLOTS is a line printer plot routine.

EMISSIONS MODEL

The emission model is a 2-D parabolic program derived from the GENMIX deck of S.V. Patankar and D. B. Spalding. The principal modifications include the addition of a 16-step reaction scheme and the ability to handle cooling slots and radial injection orifices.

The MAIN program (a computer listing has been provided in Appendix F) is concerned with input, establishment of initial conditions, logic for boundary conditions calling other subroutines in sequence, and output. The coding is similar to that already described for the liner-cooling model; therefore, only

those items unique to the emissions model will be discussed. Two additional input items are (1) extra specie-input profiles are required (MA.213 to MA.217), and (2) data describing the cooling slots and radial-injector orifices is read at MA.223 to MA.275. To accompany the additional input, there is also logic for the special boundaries, conditions associated with the cooling slots and radial injections MA.562 to MA.618 and MA.659 to MA.715, respectively. When the program reaches the edge of a slot lip, a free boundary is assumed until the flow rate of the slot has been entrained. A similar procedure is used for radial-injection orifices where the boundary is assumed to be a porous wall. All the other subroutines perform the same functions as described in the Liner-Cooling Model paragraph; however, an additional subroutine, AUXS, has been added which calculates the specie source terms and writes them on a scratch file. AUXS solves the same equations as STRIDE except that cross-stream convection and diffusion are omitted. The equations are solved many times using a step size considerably smaller than the main program. In this manner, an estimation of the change in the specie value for the larger main program marching step is obtained from which an average source term over the interval can be calculated. This is then used when the complete equations are solved in STRIDE(3). The first section of AUXS (up to AUS.68) performs data initialization followed by the calculation of forward and backward rate constants (AUS.70 to AUS.95). The main loop is entered next where first the source terms and then the derivatives are determined. Note that the rate expression for the global fuel reaction contains the effect of turbulence (AUS.125) and that the kinetic source term contains a number of variables each raised to a respective power (AUS.123 and AUS.124). These powers, EFU, ERO, etc., are read in through the name list in the MAIN program. A step size, such that the species values do not change excessively, is then selected using the variables TERM1 and TERM2, also part of the name list. Examination of AUS.223 shows that the maximum change allowed during the marching step is the larger

of TERM2 and TERM1 times the upstream specie value. The Equations are then solved and the process is repeated until a distance equal to the main program step size, DX, has been traversed. ISMAX, which is also part of the name list in the MAIN program, is a limit on the maximum number of these steps. The average source term over the interval is then calculated and stored on a scratch file for later use.

FUEL INSERTION MODEL

The function of the fuel-insertion model is to determine the evaporation rates and trajectories of a fuel spray in a two-dimensional flow field. Information concerning the fuel nozzle and flow field are read in, and from these the program calculates the fuel SMD and the trajectories. If desired, a plot of the droplet paths can be made and the evaporation rates saved for use in other programs.

INJECT1 (a computer listing has been provided in Appendix G) is the main program and controls input, output, and the other subroutines. Up to INJ.67 several data statements initialize some fuel and air properties needed in the evaporation calculations. Input data is read to INJ.119 followed by some preliminary calculations. Additional input is read at INJ.187 to INJ.195 if a nonuniform flow field is specified. Calculations of SMD for the particular fuel nozzle type selected begin at INJ.206 continuing to INJ.310. The next section entered (INJ.311 through INJ.435) loops over the five droplet sizes, calculating, in turn, their trajectories. The remainder of INJECT1 provides output and plotting. Subroutine FEVAPC is used to save the evaporation rates for later use, if desired, while AIRPRP interpolates the 2-D nonuniform flow field to obtain the free-stream conditions. Subroutine EVAP performs the majority of the calculations, including the force balances on the droplets so that their trajectories and the evaporation rates can be calculated.

Each of the remaining routines provides some property of the fuel or air required by the calculations.

IV. ILLUSTRATIONS

ANNULUS FLOW MODEL

Figure 8 shows the annulus-loss model example geometry. It is a simple reverse-flow combustor with inner- and outer-panel cooling slots, plunged primary orifices and two dome inlets. For the purposes of analysis, the annulus was divided into elements denoted by the dashed lines. These divisions correspond to places at which mass was extracted or where the annulus was of irregular shape. The elements can be length-type for which skin-friction losses and heat transfer, etc., are calculated or flow-type for which mass extraction is calculated. Thus, the length element 2 is the annulus section between the inlet 1 and 2, and flow element $\boxed{3}$ is the OD cooling slot.

Inspection of the input sheets, Figures 9 through 11, shows that Card 1 contains the case title and specifies some control parameters. The annulus-inlet conditions are specified on Card 2 along with the total number of elements used and the inlet-element number. Card 3 is for internal liner flow only and is omitted, whereas Card 4 specifies various constants. It now remains to describe the plenum and liner shape and the various orifices. This is done on the second input sheet with explanations of the various items given in Figure 11. Since, for this case, the flow split between the various orifices was known and not the orifice size, the flow-element cards are of the fixed-flow ratio type (FF). Had the orifice size been known instead, the fixed diameter type (FD) should have been used. If the C_D of a particular orifice row is known, it may be specified as has been done for flow elements 8 and 10. Even though these are actually annular slots in the dome, the program will still calculate an orifice diameter, which is, of course, meaningless; however, the effective and geometric areas are also provided in the output from which the correct annular-slot height can easily

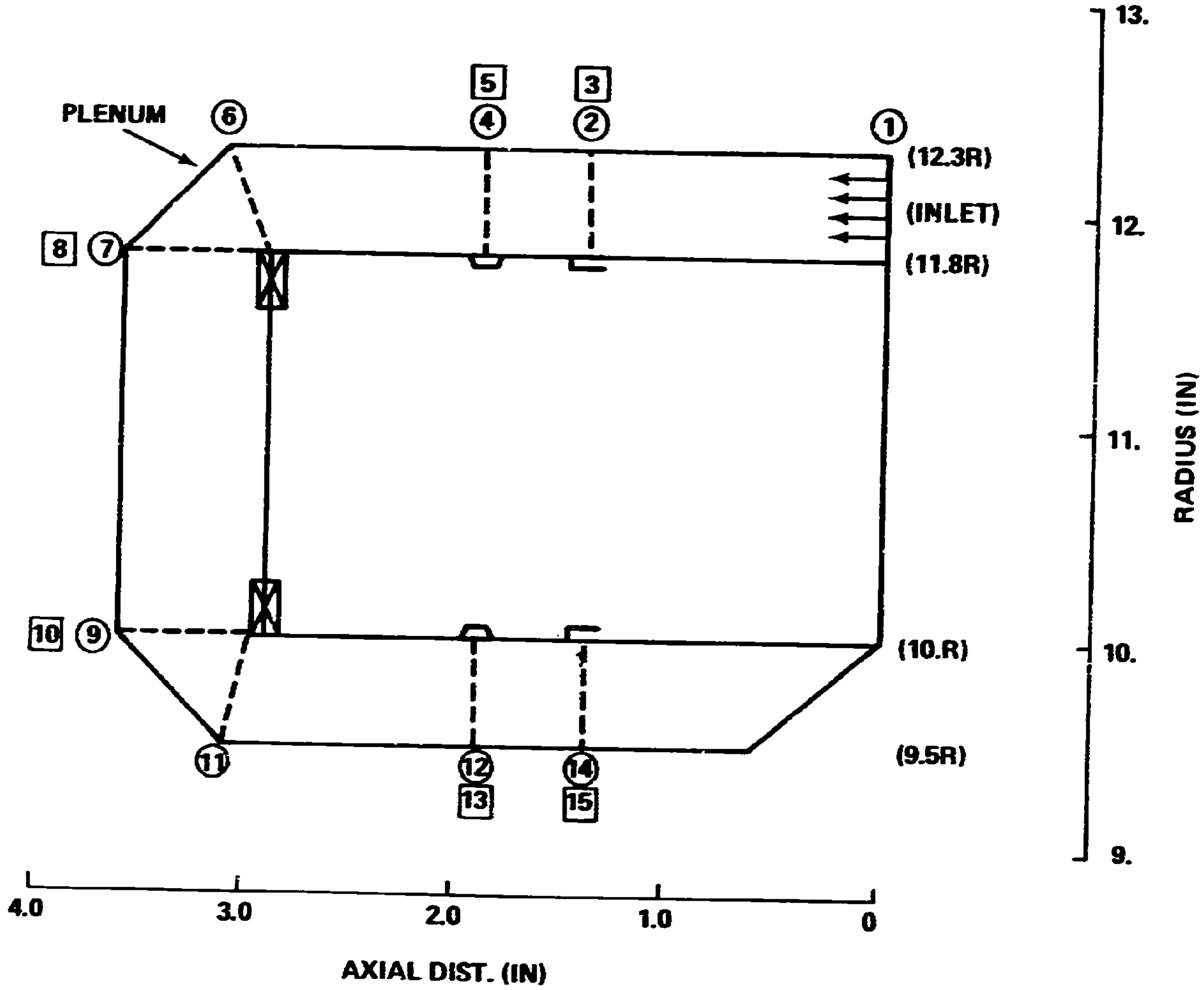


Figure 8. Annulus Loss Model Example Geometry.

	1 TITLE - MUST HAVE FOR EACH CASE	ITER 78	IPIC 79	IDBUG 80
1	ANNULUS LOSS MODEL EXAMPLE GEOMETRY	1	1	0

ANNULUS INLET FLOW CARD

	1	NEL 345	NELI 678	11 W1	21 PT1	31 TT1	41 BETA1	51 DP/P	61	71
2	I	015	001	1.6	14.7	1040.	20.	.03	—	—

DOME INLET FLOW CARD (REQUIRED FOR INTERNAL LINER FLOW ONLY)

	12	NELI 678	11 W	21 PT	31 TT	41 BETA	51	61	71
3	ID						—	—	—

CONSTANTS CARD

	1		11 FRIC	21 BLKF	31 TANS	41 CDB	51 SK	61 RG	71 IREAX
4	C	—	0.	.83	.1	1.1	1.4	53.3	0.0

1 Title - Run ident appears on printed output and plot

ITER { = 1 some (or all) holes fixed, inlet flow fixed, iterate to get pressure drop.
= 2 some (or all) holes fixed, pressure drop fixed iterate to get inlet flow (input W1 is first guess).

IPIC { = 0 no plot
= 1 plot drawn

IDBUG { = 0 output printed after converged solution
= 1 output printed after each iteration | Use only to debugg non-convergence
= 2 output printed after each element |

2 3 NEL = total number of element stations (card 2 only)
NELI = element ID no. (NELEM) at annulus or dome inlet 2 and 3

W_1 and W = air flow at inlet stations, lb/sec

PT_1 and PT = inlet total pressure, PSIA

TT_1 and TT = inlet total temperature, R

$Beta_1$, Beta = swirl angle at inlet

DP/P = total pressure drop, PSIA/PSIA (first guess if ITER = 1) card 2 only

4 FRIC { = 0, smooth wall friction factor
-1, no wall friction
= roughness factor for rough walls

BLKF = annulus effective area factor (= .83 for fully developed turbine flow)

TANS = tangent of flow separation spread angle (.1 recommended)

Figure 9. Annulus Loss Model Input Sheet (Sheet 1 of 2)

CDB = drag coefficient of struts across annulus (1→1.2 RECM)
SK = ratio of air specific heats,
RG = air gas constant

IREAX { = 0. for reverse flow annular or can combustors
= 1. for axial flow annular. First data set is for OD panel. Program expects a second set for ID panel

CASE TERMINATION

After last card of case:

o In Column 1, Column 2 blank - case repeated with changes, next card is title card followed by cards with changes from previous run.

oo In Columns 1 and 2, next card is EOF to quit or new title card followed by all cards for complete new case.

Figure 9. Annulus Loss Model Input Sheet (Sheet 2 of 2)

1	2	NELEM									
L				XP	RP	XL	RL	CL	T LINER	BLK I	DBK I
L	I			XP	RP	XL	RL	CL	T LINER	BLK I	DBK I
L	C			XP	RP	XL	RL	CL	T RISE		
F	P			W/WL	N HOLES	NHTYP	CD		I SEP		
F	D			W/WL	N HOLES	NHTYP	CD	D HOLES	I SEP		
F	B			W/WL					I SEP		
F	I			WINJ/W	V JET	ANG I	ABETA		I SEP		

	1	2	345		11	21	31	41	51	61	71	76
1	L		001		0.	12.3	0.	11.8		1760.		
2	L		002		1.4	12.3	1.4	11.8		1960.		
3	F	F	003		.15	120.	3.0			1.0		
4	L		004		1.9	12.3	1.9	11.8		1960.		
5	F	F	005		.15	30.	2.0			1.0		
6	L		006		3.1	12.3	2.9	11.8		1960.		
7	L		007		3.6	11.8	2.9	11.8		1960.		
8	F	F	008		.20	1.0	5.0	.50		1.0		
9	L		009		3.6	1.0	2.9	10.		1960.		
10	F	F	010		.20	1.0	5.0	.50		1.0		
11	L		011		3.1	9.5	2.9	10.		1960.		
12	L		012		1.9	9.5	1.9	10.		1960.		
13	F	F	013		.15	30.	2.0			1.0		
14	L		014		1.4	9.5	1.4	10.		1960		
15	F	F	015		.15	120.	3.0			1.0		
16	•	•										
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												
39												
40												

Figure 10. Sample Work Sheet for Program 117.

NELEM 1 2 3 4 5			11	21	31	41	51	61	71	76
L		0 0 1	XP	RP	XL	RL	CL	T LINER	BLK I	DBK I
L	I	0 0 2	XP	RP	XL	RL	CL	T LINER	BLK I	DBK I
L	C	0 0 3	SP	RP	XL	RL	CL	T RISE	--	--
F	F	0 0 4	W/W1	N HOLES	NHTYP	CD	--	I SEP	--	--
F	D	0 0 5	W/W1	N HOLES	NHTYP	CD	D HOLES	I SEP	--	--
F	B	0 1 0	W/W1	--	--	--	--	I SEP	--	--
F	I	0 2 0	W/INJ/W	V JET	ANGJ	ABETA	--	I SEP	--	--

ALL NUMBERS MUST HAVE DECIMAL POINTS

ELEMENT SPECIFICATION

Flow passage is divided into length (L) and flow (F) elements, element numbers, NELEM, can be in arbitrary order, i.e., 10, 1, 3, 4, 16, 30. The cards are stacked in order from inlet to last F because numbers are arbitrary, a new element can be inserted without renumbering other cards.

L. LENGTH ELEMENTS All Dimensions in Inches

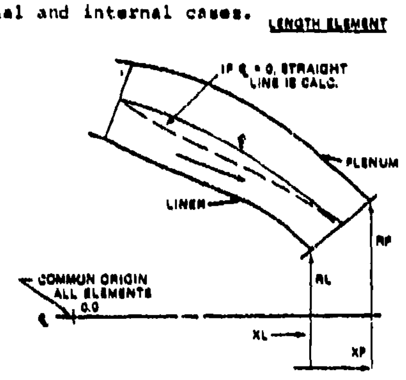
First L card is annulus inlet (CL = 0) - For both external and internal cases.

Internal and external flow cases must be run separately

For internal cases, 2nd card is dome inlet (LI) and LC cards are used with T RISE = ΔT due to combustion in this element (no L cards)

For external cases use only L Cards

XL, XP = X COORD to end of element L = Liner
RL, RP = Radius to end of element P = Plenum
(For internal flow XP, RP = OD, XL, RL = ID)
CL = Length of element (optional)
TLIN = Mean wall temp. over CL, °R
If = 0 then TLIN = TT1
BLKI = Frontal Area of Struts / Annulus Area
DBKI = Width of strut

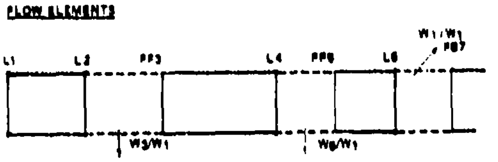


F. ORIFICE FLOW ELEMENT

F Cards are inserted between L cards at points where flow is extracted. Flow conditions into F elem. are those from upstream L elem.

Types: FF = Fixed Flow Ratio, W/W1
FD = Fixed Orf. Diam. (W/W1 is First Guess)
FB = Bleed flow (not included in liner flow)
FI = Internal flow elem. (input to these elements is obtained from an external flow solution)

W/W1 = Orifice Flow/Inlet Flow
NHOLES = No. of Orifices
NHTYP = Hole Type (For CD)
1. Flush Hole, Thin Wall
2. Plunged Hole
3. Cooling Skirt
4. Flush Hole, Thick Wall
5. CD Input
6. Rectangular Hole



CD = DISCH Coefficient (NHTYP = 5 Only)
DHOLES = Hole Diam. (For FD Only)
I SEP = 1, Separation is Reattached
VJET = Jet Injection Velocity, FPS
ANGJ = Jet Injection Angle, Deg.
ABETA = Swirl Angle in Annulus Outside FI Elem.

Figure 11. Program 117 Input Data Sheet Input Format for Element Cards Sheet 2.

be obtained. Other irregular shaped orifices, such as slotted-dilution holes, for example, can be handled in a similar manner. Card deck termination is specified by the double periods.

The output of the program is shown in Figures 12 through 14. Figure 12 is merely a printout of the input data. Figure 13 gives information of conditions in the annulus at the various stations the user has specified. Figure 14 has information regarding the orifices. Note that the program has calculated orifice-hole diameters and that the flow split is the same as was specified in the input. Overall output parameters such as pressure drop, corrected flow, etc., are also given. The numbers under the heading INPUT FOR SUB BOXES- are associated with the plot subroutine.

COMBUSTOR PERFORMANCE MODEL

The combustor geometry for the 3-D combustor-performance model example is shown in Figure 15. The reverse-flow annular liner has been divided into a grid network consisting of 30 nodes in the axial or X direction, 19 nodes in the radial or y direction, and 13 nodes in the tangential or θ directions. The decision of how large a θ segment to analyze is depending upon where radial planes of symmetry can be found, since the program assumes that there are cyclic boundary conditions in the θ direction. Therefore, any mass leaving the system along the K-13 plane is assumed to reenter the system through the K = 1 plane and vice versa. For this example, uniform grid spacing has been used, although this is obviously not required.

The completed input sheets for the case are shown in Figure 16. Additional input information can be found on the input sheet forms located in Appendix A. Cards 1 and 2 are titles used for printout and case identification. The grid size (30 by 19 by 13) has been entered on Card 3 along with indicators for axisymmetric geometry, K-ϵ viscosity model, kinetic and turbulence controlled

```
ANNULUS LOSS MODEL EXAMPLE GEOMETRY

      INPUT DATA -
        CALCULATION CONTROLS - SOME (OR ALL) HOLES FIXED SIZE, ITERATE TO FIND PRESSURE DROP (ITER = 1)
                               PICTURE WILL BE PLOTTED (IPIC = 1)
                               OUTPUT PRINTING OCCURS AFTER FINAL SOLUTION ONLY (IDBUG = 0)
        OVERALL PRESSURE DROP -  .0450
        ANNULUS EFFECTIVE AREA FACTOR -  .8300
        AIR RATIO OF SPECIFIC HEATS -   1.400
        AIR GAS CONSTANT - 53.300
        ANNULUS WALL ROUGHNESS FACTOR -  0.0000
        TANGENT OF SEPARATION SPREAD ANGLE -   .1000
        DRAG COEFFICIENT FOR INSERTED BLOCKAGE -   1.1000
        NUMBER OF POSITION ELEMENTS -  15

          DIMEN. AT DOWNSTREAM END OF ELEMENT
```

ELEM NO.	ELEM TYPE	XO OUTER LENGTH	RO OUTER RADIUS	XI INNER LENGTH	RI INNER RADIUS	CL ELEMENT LENGTH	WALL TEMP, R	INSERT AREA FACTOR	INSERT DIAMETER IN.	HOLE DIAM IN.	NUMBER OF HOLES	HOLE TYPE	DISCH COEFF	ORIFICE FLOW / FLOW IN
1	L	0.000	12.300	0.000	11.800	-0.000	1960.0	1.000	1.000					
2	L	1.400	12.300	1.400	11.800	-0.000	1960.0	1.000	1.000					
3	FF									1.0000	120	3	0.0000	.1500
4	L	1.900	12.300	1.900	11.800	-0.000	1960.0	1.000	1.000					
5	FF									1.0000	30	2	0.0000	.1500
6	L	3.100	12.300	2.900	11.800	-0.000	1960.0	1.000	1.000					
7	L	3.600	11.800	2.900	11.800	-0.000	1958.0	1.000	1.000					
8	FF									-0.0000	1	5	.5000	.2000
9	L	3.600	10.000	2.900	10.000	-0.000	1960.0	1.000	1.000					
10	FF									-0.0000	1	5	.5000	.2000
11	L	3.100	9.500	2.900	10.000	-0.000	1960.0	1.000	1.000					
12	L	1.900	9.500	1.900	10.000	-0.000	1960.0	1.000	1.000					
13	FF									1.0000	30	2	0.0000	.1500
14	L	1.400	9.500	1.400	10.000	-0.000	1960.0	1.000	1.000					
15	FF									1.0000	120	3	0.0000	.1500

```
START ITERATION NO.  1
SOLUTION CONVERGED, TOTAL JET FLOW=   1.6000 FLOW ERROR=  -.000000 FINAL PRESSURE DROP=   .045800
```

Figure 12. Annulus Loss Model Output.

ANNULUS LOSS MODEL EXAMPLE GEOMETRY

OUTPUT RESULTS - PAGE 1

ELEM NO	ELEM TYPE	SWIRL ANGLE	FLOW RATE LB/S	MACH NO	FLOW VEL FPS	AXIAL VEL FPS	TANG VEL FPS	TOTAL TEMP, R	STATIC TEMP, R	TOTAL PRESS, PSIA	STATIC PRESS, PSIA	DENSITY LB/FT3	DYNAM HEAD, PSIA	DYN HD /PTOT —
1	L	20.00	1.600	.1306	206.09	193.66	70.49	1040.0	1036.5	14.70	14.53	.0379	.174	.0118
2	L	19.76	1.600	.1311	207.75	195.57	70.08	1049.6	1046.0	14.69	14.52	.0375	.175	.0119
3	FF	22.89	1.360	.1136	180.08	165.88	70.08	1049.6	1046.9	14.69	14.56	.0376	.131	.0089
4	L	22.76	1.360	.1137	180.56	166.46	69.90	1053.2	1050.5	14.69	14.56	.0374	.132	.0090
5	FF	27.04	1.120	.0967	153.67	136.86	69.90	1053.2	1051.3	14.69	14.59	.0375	.096	.0065
6	L	28.45	1.120	.0913	145.65	128.05	69.41	1061.7	1059.9	14.69	14.60	.0372	.085	.0058
7	L	30.10	1.120	.0883	140.97	121.94	70.73	1064.2	1062.5	14.69	14.61	.0371	.080	.0054
8	FF	44.52	.800	.0631	100.85	71.87	70.73	1064.2	1063.3	14.69	14.65	.0372	.041	.0028
9	L	43.70	.800	.0740	118.85	85.90	82.14	1076.8	1075.6	14.68	14.63	.0367	.056	.0038
10	FF	57.89	.480	.0603	96.94	51.49	82.14	1076.8	1076.0	14.68	14.65	.0368	.037	.0025
11	L	50.55	.480	.0674	108.49	68.89	83.81	1086.2	1079.2	14.68	14.64	.0366	.047	.0032
12	L	47.66	.480	.0689	111.47	75.04	82.44	1092.1	1091.0	14.68	14.63	.0362	.049	.0033
13	FF	65.51	.240	.0559	90.56	37.49	82.44	1092.1	1091.4	14.68	14.65	.0363	.032	.0022
14	L	64.98	.240	.0551	89.53	37.81	81.16	1101.4	1100.7	14.68	14.65	.0360	.031	.0021
15	FF	89.69	.002	.0499	81.16	.38	81.16	1101.4	1100.8	14.68	14.65	.0360	.026	.0017

Figure 13. Annulus Loss Model Output.

ANNULUS LOSS MODEL EXAMPLE GEOMETRY

OUTPUT RESULTS - PAGE 2

ELEM NO.	ELEM TYPE	MEAN RADIUS IN.	CHANNEL WIDTH IN.	ANN AREA IN2	AN EFF AREA IN2	WAKE AREA FACTOR	SEPAR AREA FACTOR	ATTCH LENGTH IN.	HOLE DIAM IN.	DISCH COEFF -	JET ANGLE DEG	ORIF GEOM AREA	ORIF EFF AREA	ORIF CUMUL EF AREA	JET VELOCITY FPS	ORIF FLOW /MIN
		/*********** ANNULUS GEOMETRIC PARAMETERS ******** /							******************* ORIFICE PARAMETERS ********************							
1	L	12.050	.500	37.86	29.53	1.000	1.000	0.000								
2	L	12.050	.500	37.86	29.58	1.000	1.000	0.000								
3	FF	12.050	.500	37.86	28.94	1.000	1.000	0.000	.1877	.6847	0.00	3.321	2.273	2.273	405.44	.1500
4	L	12.050	.500	37.86	28.97	1.000	1.000	0.000								
5	FF	12.050	.500	37.86	27.98	1.000	1.000	0.000	.3542	.7700	80.00	2.955	2.276	4.549	405.64	.1500
6	L	12.050	.539	40.77	29.75	1.000	1.000	.343								
7	L	11.800	.700	51.90	30.81	1.000	.827	0.000								
8	FF	11.800	.700	51.90	30.70	1.000	1.000	0.000	2.7873	.5000	90.00	6.102	3.051	7.600	406.68	.2000
9	L	10.000	.700	43.98	26.38	1.000	1.000	0.000								
10	FF	10.000	.700	43.98	19.39	1.000	1.000	0.000	2.7968	.5000	90.00	6.144	3.072	10.672	408.31	.2000
11	L	9.750	.539	32.99	17.39	1.000	1.000	0.000								
12	L	9.750	.500	30.63	17.11	1.000	1.000	0.000								
13	FF	9.750	.500	30.63	10.52	1.000	1.000	0.000	.3375	.8665	80.00	2.684	2.325	12.997	410.18	.1500
14	L	9.750	.500	30.63	10.74	1.000	1.000	0.000								
15	FF	9.750	.500	30.63	.12	1.000	1.000	0.000	.1716	.8413	0.00	2.776	2.336	15.333	411.58	.1500

```
OVERALL FLOW COEFFICIENT =      .6282
INLET CORRECTED FLOW, LB/S =    2.266
DISCHARGE PRESSURE, PSIA =     14.04
PRESSURE DROP / PT INLET   =    .0450
TOTAL GEOMETRIC AREA, IN2 =    23.981

INPUT FOR SUB BOXES -
  2.750  -1.850  -7.850    .500  -7.850  -1.500   0.000   0.000   0.000  -4.700   6.550   8.855  -8.225
-3.075 2.350  1    -2.050 2.350  2    -2.050 4.575  3    -1.025 2.350  4
-1.025 4.575  5      .000 2.350  6     1.025 2.350  7     1.025 4.575  8
 2.050 2.350  9     2.050 4.575 10     1.537-4.450 11      .512-4.450 12
  .512-6.225 13     -.513-4.450 14     -.513-5.225 15
```

Figure 14. Annulus Loss Model Output.

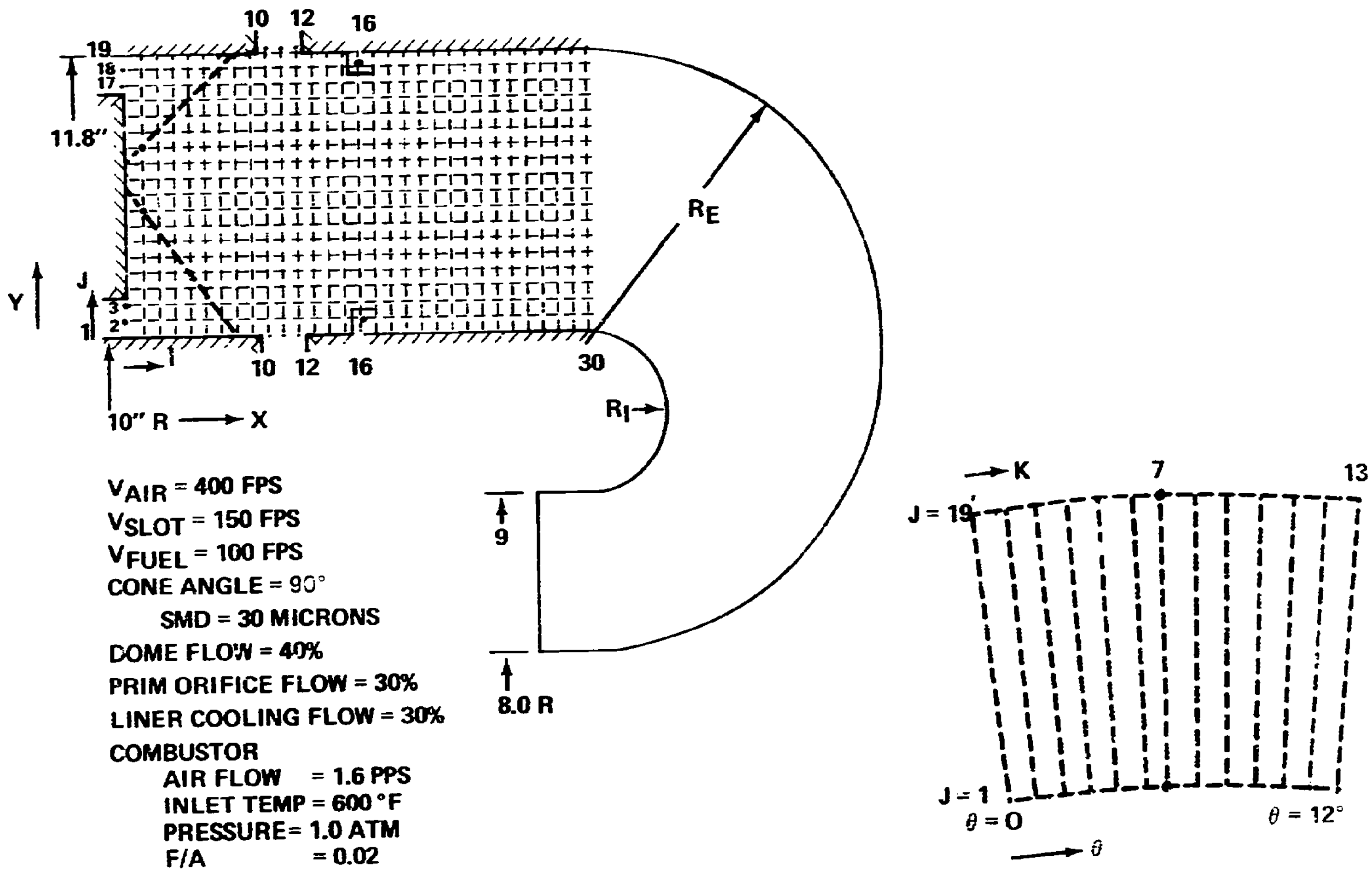


Figure 15. Combustor Geometry for 3-D Combustor-Performance Model.

22 VARIABLE TITLE CARDS (4A10) SAME ORDER AS IMPRINT

Card								
1								

CASE TITLE CARD (8A10)

Card								
2	3D PER	FORMANC	E MOD	EL EXA	MPLE CA	SE		

Card	LP1	MP1	LP1	IPLAX	MODEL	MODER	IPAR	ITRAD
3	30	19	13	02	02	02	02	02

Card	IU	MODEN	INTAPE	IDW	IRES			
4	02	02	00	01	00			

ISOLVE (8(I2, 8X))

Card	U	V	W	P'	KE	ε	Φ	MFU
5	01	01	01	01	01	01	01	01

	MCO	$\tilde{h}$	FX	FY	FZ			
	01	01	01	01	01			

ICTDMA (8(I2, 8X))

Card	U	V	W	P'	KE	ε	Φ	MFU
6	01	01	01	06	01	01	01	01

	MCO	$\tilde{h}$						
	01	01						

IMPRINT (8(I2, 8X))

Card	U	V	W	PRESS	KE	ℓm	Φ	MFU
7	06	06	06	06	06	06	06	06

Figure 16. 3-D Combustor Performance Model (1 of 6)

TEMP	$\tilde{h}$	Favg	Fx	Fy	Fz	MCO	MH2O
06			06	06	06	06	

MO2	MCO2	MN2	μEFF	DENSITY	EVAP		
			06	06	06		

RELAXATION PARAMETERS (8E10.4)

8

U	V	W	P'	KE	ε	Φ	MFU
.2	.2	.2	1.0	.5	.5	.8	.8

MCO	$\tilde{h}$	Fx	Fy	Fz	PRESS	DENSITY	VISCOS
.8	.8	1.	1.	1.	.5	.2	.1

LAMINAR PRANDTL NUMBERS (8E10.4)

9

U	V	W	P'	KE	ε	Φ	MFU
1.	1.	1.	1.	1.	.7	.7	.7

MCO	$\tilde{h}$						
.7	.7						

TURBULENT PRANDTL NUMBERS (8E10.4)

10

U	V	W	P'	KE	ε	Φ	MFU
1.	1.	1.	1.		.9	.9	.9

MCO	$\tilde{h}$						
.9	.9						

X-COORDINATES (1-LP1) (8E10.4)

11

0.	.1	.2	.3	.4	.5	.6	.7
.8	.9	1.0	1.1	1.2	1.3	1.4	1.5

Figure 16. 3-D Combustor Performance Model (2 of 6)

1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3

2.4 2.5 2.6 2.7 2.8 2.9

RI Y-COORDINATES (2-MP1) (8E10.4)

12

10.	.1	.2	.3	.4	.5	.6	.7

.8	.9	1.0	1.1	1.2	1.3	1.4	1.5

1.6	1.7	1.8					

Z-COORDINATES (1-NP1) (8E10.4)

13

0.	1.	2.	3.	4.	5.	6.	7.

8.	9.	10.	11.	12.			

IWEI JWIO (2(I2,8X))

14

02	19						

IWLI VALUES (8(I2,8X)) (SKIP 15 AND 16 IF IWEI = 2)

15

Figure 16. 3-D Combustor Performance Model (3 of 6)

JWLO VALUES (8(I2, 8X))

16

(8E10.4)

17

PRESS	DEN	ABSOR	SCATR	AKFAC	ALFAC		
1.0	—	.1	.01	.003	.02		

(8E10.4)

18

CX	HY	HFU	FUMCO				
1.0	19.28	-49317.	.00001				

(8E10.4)

19

PREXP1	ARCON1	CR1	PREXP2	ARCON2	CR2		
3.3E+14	27000.	3.0	6.0E+8	12500.	4.0		

(8E10.4)

20

C1	C2	CD	AMU	ERROR	TCYLW	TINLW	TLIP
1.43	1.92	.09	185E-5	.01	1960.	1960.	1560.

(2(I3, 7X), 6(I2, 8X))

21

LASTEP	IJUMP	JSW1	JSW2	NUINJ	NVINJ		
150	999	02	03	02	06		

(8E10.4)

22

USW	VSW	SWNO	AFSW	FSW	TSW		
400.	0.	0.	.02133	0.0	1060		

23

NFNZ	ISPRAY	TFUEL					
01	9	540					

24

XO	YO	ZO	ALFA	BETA	DELTA	THETA 1	THETA 2
.05	.9	6.0	90	-90.	0.0	0.	360.

(SKIP 24 IF NFNZ = 00)

RSP	WF	SMD	VFUEL				
20.	.001067	30.	100				

Figure 16. 3-D Combustor Performance Model (4 of 6)

(SKIP CARDS 25 → 30 IF NUINJ = 00)

I - LOCATION OF COOLING SLOTS (8(I2, 8X))

25	17	17						

J - LOCATION OF COOLING SLOTS (8(I2, 8X))

26	02	18						

AXIAL SLOT VELOCITY (8E10.4)

27	150.	150.						

TANG. SLOT VELOCITY (8E10.4)

28	0.	0.						

SLOT FLOW RATE (8E10.4)

29	.008	.008						

SLOT TEMPERATURE (8E10.4)

30	1060.	1060.						

(SKIP CARDS 31 → 38 IF NVINJ = 00)

I - LOCATION OF RADIAL INJECTION (8(I2.8X))

31	10	11	12	10	11	12		

J - LOCATION OF RADIAL INJECTION (8(I2, 8X))

32	01	01	01	19	19	19		

K - LOCATION OF RADIAL INJECTION (8(I2, 8X))

33	07	07	07	07	07	07		

INJECTION VELOCITY (8E10.4)

34	400.	400.	400.	-400.	-400.	-400.		

Figure 16. 3-D Combustor Performance Model (5 of 6)

INJECTION TURBULENT KINETIC ENERGY (8E10.4)

35								
	480.	480.	480.	480.	480.	480.		

INJECTION TURBULENT LENGTH SCALE (8E10.4)

36								
	.0005	.0005	.0005	.0005	.0005	.0005		

INJECTION FLOW RATE (8E10.4)

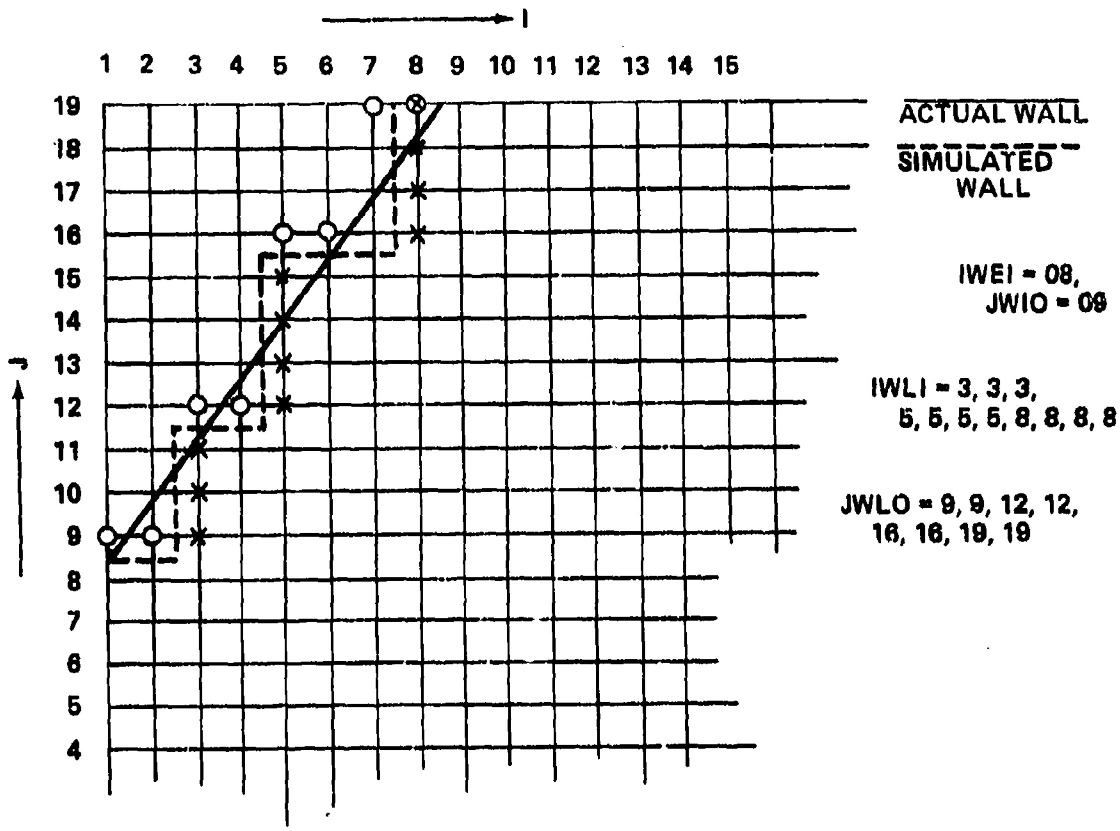
37								
	.002667	.002667	.002667	.002667	.002667	.002667		

INJECTION TEMPERATURE (8E10.4)

38								
	1060.	1060.	1060.	1060.	1060.	1060.		

Figure 16. 3-D Combustor Performance Model (6 of 6)

combustion, relative pressure, and radiation to be included, respectively. The use of relative pressure, rather than absolute pressure, merely means that the pressure field is referenced to one particular grid node by subtracting that pressure value from the entire field. On Card 4, the user-selected-input units have been specified. The particular units employed are combinations of convenient ones and are specified by data statements in the main program, at lines MA.9 to MA.11. The user should redefine the arrays for his own input units or use S.I. by specifying IU = 01. Specifying the perfect gas-density calculation, not printing the initial values, the inner boundary as a wall and that this is not a restart, complete the information on Card 4. In order to restart a case, Tape 8 must be saved from the previous run and be made available to the program. Card 5 indicates that all the variables are to be solved. P' is the pressure perturbation used in the solution algorithm, h is stagnation enthalpy, and F_x, F_y, and F_z are the three radiation fluxes. Card 6 shows that all the variables will receive one sweep of the solution routine per iteration except P', which will have six. The solution of the equations in early iterations is not exact, but this does not present a problem since the coefficients are changing from iteration to iteration anyway. However, it is beneficial to the convergence rate to obtain a more accurate solution to the P' equation. The variables to be printed are specified on Card 7. The 06 merely indicates that every 6th K-plane will be printed. The relaxation parameters specified on Card 8 have been used successfully on a wide range of problems and probably need not be altered. The Prandtl numbers and coordinates, Cards 9 through 13, are fairly self explanatory except that the first field, Card 12, is the radius of the inner boundary and that values of y(2) to y(MPL) are measured from that line. Cards 14 through 16 are used to specify an inclined wall at the inlet. Since there is none for this case, the values of IWEI and JWIO are set equal to 2 and MP1 (i.e., 19) respectively, and Cards 15 and 16 are omitted. Were there an inclined wall, Figure 17 gives the necessary information



THE ACTUAL WALL IS SIMULATED BY STAIRSTEPS ALONG THE MIDPOINTS BETWEEN NODES. JWIO IS THE J-NODE WHERE THE INCLINED WALL STARTS, i.e.,09, AND IWEI IS THE I-NODE WHERE THE INCLINED WALL ENDS, i.e.,08. IWLI IS THE 1ST I-NODE INSIDE THE SIMULATED WALL AT A PARTICULAR J-LOCATION. ELEVEN VALUES ARE REQUIRED SINCE THIS IS THE NUMBER OF J-NODES INCLUDED IN THE INCLINED WALL, J = 9 - 19, AND ARE MARKED BY ✱. JWLO IS THE 1ST J-NODE OUTSIDE THE SIMULATED WALL AT A PARTICULAR I-LOCATION. EIGHT VALUES ARE REQUIRED SINCE THIS IS THE NUMBER OF I-NODES INCLUDED IN THE INCLINED WALL, I = 1 - 8, AND ARE MARKED BY ⌖.

Figure 17. Information Necessary to Describe an Inclined Wall.

required to describe it. Cards 17 through 20 need no further explanation other than that given in input sheet forms. A total of 150 iteration steps, along with no intermediate printout, have been specified in the first two fields of Card 21. The basic program contains provisions for only one dome inlet, specified by JSW1 and JSW2; however, the example problem has two. The second inlet was handled by internal modifications to the program in the Subroutine ALLMOD, a process required on nearly every combustor analyzed, as a code which makes provisions for all possible configurations would be extremely complex and lengthy. Note that each primary orifice is simulated by three nodes, making the total of radial-injection points equal to six. Inlet conditions for the dome are provided on Card 22, while Cards 23 and 24 describe the fuel nozzle. A back angle (β) of zero would have the nozzle spraying in a purely tangential and in an increasing θ direction. Positive β would have the spray cone rotated toward the dome; therefore, a value of -90 degrees has the spray cone directed axially along the combustor as is required. Zero down angle (δ) was needed for this example. A positive value would, however, rotate the spray cone toward the inner wall. For geometries that have the entire spray cone in the calculation domain, such as this annular one, THETA1 and THETA2 <u>never</u> change from 0 and 360 degrees or their equivalent in whatever angular input units are selected. Cards 25 through 30 are used to describe the cooling slots, of which two were specified (NUINJ = 2 on Card 21). Note that even though the slots surround I-node 16, the I location is specified as one greater (or 17) due to internal conveniences in the program. Similarly, Cards 31 through 38 specify the radial injection points. Due to the sign convention on V-velocity (positive is in the positive y-direction), injection points on the outer wall have a negative V-velocity component, as shown on the last three fields of Card 34.

The output of the 3-D model is illustrated in Figure 18 (7 sheets). Sheet 1 is a printout of some input data, including fuel and air flow rates, injection velocities, and other important quantities. Note that the output units here are S.I. Sheets 2 and 3 show the u-velocities at θ = 6 deg (in line with the primary holes) after 150 iterations. The total error in mass, i.e., the sum of the mass error in all the grid cells, was 1.5 percent of the total flow, which was deemed accurate enough for this example. The two dome inlets J = 2-3 and J = 17-18 can be seen at I = 2. The u-velocities are calculated for slightly different control volumes than the other variables. The U-velocity printed at I = 8, for example is actually the U-velocity that occurs at the cell boundary between I = 7 and I = 8. This displacement results in the inlet U-velocity being stored at I = 2 rather than I = 1. A small recirculation zone exists behind the dome and is terminated by the primary orifices at I = 10, 11, and 12. Small recirculation regions are also evident behind each jet at I = 14, while the presence of the two cooling slots can be seen at I = 16 and 17. Sheets 3 and 4 of Figure 18 show the fuel mass fractions for the same θ plane. The figure also shows the extremely rich regions just behind the dome at I = 2-4 near the fuel nozzle. By the time the exit plane is reached, some unburned fuel still remains. Temperature is shown in Sheets 5 and 6. The fuel-rich region behind the dome (seen in Figure 15) exists at a relatively low temperature as the amount of oxygen is very limited. Farther down the combustor where the primary jets have recirculated (I = 6,7) one sees temperatures closer to stoichiometric. The primary jets penetrate to the combustor centerline as evidenced by the temperature profile at I = 12. These jets produce a colder core with hot regions on either side that extend well past the cooling slots at I = 16. These slots provide a cool film that extends to the exit of the combustor. Sheets 6 and 7 show the evaporation rate of liquid fuel. One can clearly see the two sides of the spray cone and that some fuel is impinging on the wall at I = 9. Practically all the fuel has evaporated

3D PERFORMANCE MODEL EXAMPLE CASE

I. PHYSICAL INPUT

1.FUEL -

HYDROGEN-CARBON RATIO	1.9280E+00	
MOLECULAR WEIGHT	1.3928E+02	(KG/KGMOLE)
HEAT OF FORMATION	-4.9317E+04	(CAL/GMOLE)
INLET-1 MASS FLOW RATE	0.0	(KG/S)

2.AIR -

PRESSURE	1.0133E+05	(NEW/SQ.M)
INLET-1 MASS FLOW PATE	9.6753E-03	(KG/S)
INLET-1 AXIAL VELOCITY	1.2192E+02	(M/S)
INLET-1 SWIRL NUMBER	0.0	

II. GEOMETRICAL INPUT

CHANNEL HEIGHT OF COMBUSTOR	9.1440E-02	(M)
LENGTH OF COMBUSTOR	7.3660E-02	(M)
ANGULAR SECTOR	2.0940E-01	(RAD-M)
INLET-1 FLOW AREA	7.3628E-04	(SQ.M)

III. AIR INJECTIONS

1.FILM COOLING AIR-

SLOT NO	I	J	K	U-VELOCITY (M/S)	V-VELOCITY (M/S)	W-VELOCITY (M/S)	MASS FLOW (KG/S)	FUEL FLOW (KG/S)
1	17	2	***	4.572E+01	2.545E-73	0.0	3.629E-03	
2	17	18	***	4.572E+01	2.545E-73	0.0	3.629E-03	

2.DILUTION AND SECONDARY AIR-

SLOT NO	I	J	K	U-VELOCITY (M/S)	V-VELOCITY (M/S)	W-VELOCITY (M/S)	MASS FLOW (KG/S)	FUEL FLOW (KG/S)
1	10	1	7	2.545E-73	1.219E+02	2.545E-73	1.210E-03	
2	11	1	7	2.545E-73	1.219E+02	2.545E-73	1.210E-03	
3	12	1	7	2.545E-73	1.219E+02	2.545E-73	1.210E-03	
4	10	19	7	2.545E-73	-1.219E+02	2.545E-73	1.210E-03	
5	11	19	7	2.545E-73	-1.219E+02	2.545E-73	1.210E-03	
6	12	19	7	2.545E-73	-1.219E+02	2.545E-73	1.210E-03	

3.FUEL NOZZLES-

XO (M)	YO (M)	ZO (M-R)	ALFA (RAD)	BETA (RAD)	DELTA (RAD)	THETA1 (RAD)	THETA2 (RAD)	NSL -	WF (KG/S)	SMD (MICRON)	VFUEL (M/S)
1.27E-03	2.29E-02	1.05E-01	1.57E+00	-1.57E+00	0.0	0.0	6.28E+00	2.00E+01	4.84E-04	3.00E+01	3.05E+01

IV. AIR-FUEL BALANCE

TOTAL FUEL FLOW RATE	4.8399E-04	(KG/S)
TOTAL AIR FLOW RATE	2.4191E-02	(KG/S)
FUEL TO AIR RATIO	2.0007E-02	

Figure 18. 3-D Performance Model Output (Sheet 1 of 7).

V. SOME IMPORTANT QUANTITIES

SPECIFIC HEAT	1.1578E+03	(J/KG-K)
ACTIVATION ENERGY (1ST)	2.7000E+04	(K)
PRE-EXPONENT (1ST)	3.3000E+14	
EDDY BREAKUP CONSTANT (1ST)	3.0000E+00	
ACTIVATION ENERGY (2ND)	1.2500E+04	(K)
PRE-EXPONENT (2ND)	6.0000E+08	
EDDY BREAKUP CONSTANT (2ND)	4.0000E+00	
TURB. CONSTANT (C1)	1.4300E+00	
TURB. CONSTANT (C2)	1.9200E+00	
TURB. CONSTANT (CD)	9.0000E-02	
ABSORPTION COEFFICIENT	1.0000E-01	
SCATTERING COEFFICIENT	1.0000E-02	

U-VELOCITY(M/SEC)

K = 7

J \ I =	2	3	4	5	6	7	8	9	10	11	12	13
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	1.22E+02	4.47E+01	5.23E+01	5.37E+01	5.29E+01	4.99E+01	4.39E+01	3.06E+01	-1.72E+00	3.34E+00	4.58E+00	1.42E+01
17	1.22E+02	6.07E+01	6.45E+01	6.33E+01	5.94E+01	5.33E+01	4.36E+01	2.83E+01	6.22E+00	7.74E+00	5.40E+00	6.86E+00
16	0.0	-3.84E+00	9.93E+00	2.31E+01	3.10E+01	3.47E+01	3.32E+01	2.61E+01	9.30E+00	1.01E+01	6.25E+00	5.42E+00
15	0.0	-1.07E+00	-1.92E+00	5.53E+00	1.43E+01	2.04E+01	2.37E+01	2.29E+01	8.97E+00	1.08E+01	6.85E+00	5.73E+00
14	0.0	2.04E+00	-4.27E-01	-3.40E-01	5.76E+00	1.14E+01	1.62E+01	1.88E+01	9.15E+00	9.63E+00	6.94E+00	7.11E+00
13	0.0	4.41E+00	2.55E+00	1.28E+00	1.11E+00	4.46E+00	9.49E+00	1.50E+01	4.51E+00	5.10E+00	6.13E+00	1.39E+01
12	0.0	4.62E+00	2.84E+00	5.40E-02	-3.74E+00	-3.22E+00	8.51E-01	-1.27E+00	-1.47E+01	-5.64E+00	5.22E+00	2.03E+01
11	0.0	2.97E+00	-1.33E+00	-2.30E+01	-2.16E+01	-3.09E+01	-4.18E+01	-5.26E+01	-5.37E+01	-2.92E+01	2.54E+00	4.20E+01
10	0.0	-1.07E+01	-2.39E+01	-3.32E+01	-4.37E+01	-5.60E+01	-6.62E+01	-7.29E+01	-6.48E+01	-3.20E+01	6.48E+00	4.50E+01
9	0.0	1.27E+00	-2.89E+00	-9.87E+00	-1.16E+01	-1.14E+01	-1.26E+01	-1.94E+01	-2.46E+01	-6.55E+00	6.29E+00	2.15E+01
8	0.0	4.05E+00	2.00E+00	-8.54E-01	-3.19E+00	-4.21E-01	4.64E+00	1.06E+01	2.49E+00	5.20E+00	6.13E+00	9.63E+00
7	0.0	4.64E+00	2.74E+00	1.51E+00	2.01E+00	6.69E+00	1.22E+01	1.67E+01	1.06E+01	1.01E+01	6.53E+00	4.30E+00
6	0.0	3.16E+00	8.20E-01	1.56E+00	7.40E+00	1.37E+01	1.90E+01	2.14E+01	1.07E+01	1.18E+01	6.59E+00	2.32E+00
5	0.0	6.39E-01	-7.13E-01	6.07E+00	1.64E+01	2.28E+01	2.62E+01	2.46E+01	1.04E+01	1.19E+01	6.12E+00	1.90E+00
4	0.0	-2.16E+00	1.26E+01	2.54E+01	3.30E+01	3.58E+01	3.50E+01	2.67E+01	9.35E+00	1.07E+01	5.40E+00	2.26E+00
3	1.22E+02	6.04E+01	6.40E+01	6.29E+01	5.95E+01	5.35E+01	4.41E+01	2.69E+01	6.20E+00	7.64E+00	4.80E+00	5.14E+00
2	1.22E+02	4.62E+01	5.17E+01	5.32E+01	5.25E+01	4.99E+01	4.42E+01	3.01E+01	-7.44E+00	2.13E+00	4.87E+00	1.86E+01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I =	14	15	16	17	18	19	20	21	22	23	24	25
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	-1.17E+01	-2.10E-01	5.29E-33	4.57E+01	3.38E+01	3.53E+01	3.54E+01	3.52E+01	3.48E+01	3.43E+01	3.39E+01	3.35E+01
17	-1.34E+00	3.28E+00	2.76E+01	2.61E+01	1.79E+01	1.69E+01	1.71E+01	1.75E+01	1.81E+01	1.87E+01	1.93E+01	2.00E+01
16	5.59E-01	4.21E+00	2.35E+01	2.82E+01	2.79E+01	2.76E+01	2.75E+01	2.74E+01	2.73E+01	2.71E+01	2.68E+01	2.66E+01
15	1.04E+00	3.49E+00	1.83E+01	2.55E+01	2.83E+01	2.94E+01	2.99E+01	3.00E+01	3.00E+01	2.99E+01	2.97E+01	2.96E+01
14	3.03E+00	2.10E+00	1.43E+01	2.22E+01	2.66E+01	2.89E+01	3.01E+01	3.06E+01	3.08E+01	3.09E+01	3.08E+01	3.07E+01
13	9.50E+00	4.32E+00	1.20E+01	2.03E+01	2.52E+01	2.81E+01	2.98E+01	3.07E+01	3.12E+01	3.14E+01	3.14E+01	3.14E+01
12	2.43E+01	1.91E+01	1.83E+01	2.18E+01	2.57E+01	2.84E+01	3.04E+01	3.15E+01	3.22E+01	3.25E+01	3.25E+01	3.25E+01
11	5.38E+01	5.16E+01	4.54E+01	4.06E+01	3.76E+01	3.60E+01	3.53E+01	3.50E+01	3.48E+01	3.46E+01	3.44E+01	3.43E+01
10	5.92E+01	6.01E+01	5.70E+01	5.34E+01	5.04E+01	4.80E+01	4.61E+01	4.44E+01	4.28E+01	4.15E+01	4.02E+01	3.92E+01
9	2.44E+01	1.91E+01	1.80E+01	2.13E+01	2.48E+01	2.79E+01	3.03E+01	3.20E+01	3.31E+01	3.38E+01	3.42E+01	3.43E+01
8	4.92E+00	-2.59E+00	7.07E+00	1.55E+01	2.08E+01	2.44E+01	2.67E+01	2.81E+01	2.90E+01	2.95E+01	2.98E+01	2.99E+01
7	-1.77E+00	-2.59E+00	8.06E+00	1.62E+01	2.13E+01	2.44E+01	2.62E+01	2.72E+01	2.77E+01	2.80E+01	2.81E+01	2.82E+01
6	-1.77E+00	2.45E-01	1.16E+01	1.92E+01	2.33E+01	2.54E+01	2.65E+01	2.70E+01	2.72E+01	2.73E+01	2.72E+01	2.72E+01
5	-1.44E+00	2.39E+00	1.64E+01	2.30E+01	2.56E+01	2.62E+01	2.64E+01	2.65E+01	2.64E+01	2.63E+01	2.62E+01	2.60E+01
4	-1.76E+00	3.07E+00	2.21E+01	2.59E+01	2.56E+01	2.48E+01	2.44E+01	2.42E+01	2.40E+01	2.38E+01	2.36E+01	2.35E+01
3	-3.78E+00	1.88E+00	2.71E+01	2.41E+01	1.67E+01	1.55E+01	1.56E+01	1.60E+01	1.65E+01	1.72E+01	1.79E+01	1.86E+01
2	-1.42E+01	-2.19E+00	4.53E-33	4.57E+01	3.65E+01	3.74E+01	3.72E+01	3.68E+01	3.62E+01	3.57E+01	3.52E+01	3.47E+01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 18. 3-D Performance Model Output (Sheet 2 of 7).

U-VELOCITY (M/SEC)

J	I = 26	27	28	29	30
19	0.0	0.0	0.0	0.0	0.0
18	3.32E+01	3.28E+01	3.26E+01	3.25E+01	3.26E+01
17	2.07E+01	2.13E+01	2.20E+01	2.27E+01	2.28E+01
16	2.64E+01	2.63E+01	2.62E+01	2.61E+01	2.63E+01
15	2.94E+01	2.92E+01	2.91E+01	2.91E+01	2.92E+01
14	3.06E+01	3.05E+01	3.05E+01	3.06E+01	3.07E+01
13	3.14E+01	3.14E+01	3.15E+01	3.16E+01	3.17E+01
12	3.25E+01	3.26E+01	3.27E+01	3.29E+01	3.30E+01
11	3.42E+01	3.41E+01	3.42E+01	3.45E+01	3.46E+01
10	3.82E+01	3.75E+01	3.70E+01	3.69E+01	3.70E+01
9	3.43E+01	3.43E+01	3.42E+01	3.44E+01	3.45E+01
8	3.00E+01	3.01E+01	3.02E+01	3.04E+01	3.06E+01
7	2.82E+01	2.83E+01	2.84E+01	2.86E+01	2.87E+01
6	2.71E+01	2.72E+01	2.72E+01	2.73E+01	2.74E+01
5	2.59E+01	2.58E+01	2.58E+01	2.58E+01	2.59E+01
4	2.35E+01	2.35E+01	2.35E+01	2.35E+01	2.36E+01
3	1.94E+01	2.01E+01	2.08E+01	2.15E+01	2.16E+01
2	3.43E+01	3.39E+01	3.35E+01	3.34E+01	3.35E+01
1	0.0	0.0	0.0	0.0	0.0

FUEL MASS FRACTION

K = 7

J	I = 1	2	3	4	5	6	7	8	9	10	11	12
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	1.37E-02	1.46E-02	1.47E-02	1.44E-02	1.42E-02	1.41E-02	1.39E-02	1.55E-02	8.44E-04	4.89E-04	1.98E-03
17	0.0	5.10E-02	4.35E-02	3.58E-02	2.89E-02	2.21E-02	1.61E-02	1.55E-02	1.20E-02	1.20E-03	5.25E-04	1.93E-03
16	0.0	2.06E-01	1.31E-01	7.50E-02	5.29E-02	3.88E-02	3.64E-02	2.74E-02	1.24E-02	1.65E-03	5.99E-04	1.87E-03
15	0.0	2.28E-01	1.84E-01	9.98E-02	5.89E-02	5.68E-02	5.24E-02	3.66E-02	1.47E-02	2.22E-03	7.08E-04	1.81E-03
14	0.0	2.40E-01	2.45E-01	1.76E-01	1.04E-01	8.31E-02	6.04E-02	4.36E-02	2.06E-02	3.06E-03	8.47E-04	1.76E-03
13	0.0	2.48E-01	3.03E-01	3.25E-01	2.14E-01	1.08E-01	6.72E-02	4.81E-02	2.66E-02	3.66E-03	9.57E-04	1.72E-03
12	0.0	2.62E-01	3.75E-01	3.78E-01	2.22E-01	1.03E-01	6.40E-02	4.44E-02	1.36E-02	3.50E-03	9.58E-04	1.69E-03
11	0.0	3.03E-01	4.66E-01	2.63E-01	1.29E-01	5.16E-02	2.34E-02	1.17E-02	4.60E-03	2.73E-03	9.59E-04	1.66E-03
10	0.0	2.69E-01	2.55E-01	1.53E-01	7.29E-02	2.97E-02	1.35E-02	8.27E-03	5.48E-03	4.80E-03	1.83E-03	9.69E-04
9	0.0	3.26E-01	4.95E-01	2.99E-01	1.84E-01	1.13E-01	7.96E-02	4.98E-02	2.36E-02	7.60E-03	1.93E-03	8.91E-04
8	0.0	2.92E-01	4.24E-01	4.20E-01	2.43E-01	1.39E-01	1.01E-01	7.91E-02	5.42E-02	8.12E-03	1.93E-03	8.36E-04
7	0.0	2.79E-01	3.58E-01	3.86E-01	2.30E-01	1.39E-01	9.92E-02	7.67E-02	4.39E-02	7.31E-03	1.72E-03	7.86E-04
6	[illegible]	2.72E-01	3.13E-01	2.44E-01	1.52E-01	1.18E-01	9.00E-02	6.94E-02	3.88E-02	4.84E-03	1.38E-03	7.41E-04
5	0.0	2.66E-01	2.62E-01	1.49E-01	9.99E-02	8.95E-02	7.90E-02	5.94E-02	2.70E-02	2.96E-03	1.12E-03	6.98E-04
4	0.0	[illegible]	1.96E-01	1.23E-01	8.83E-02	6.64E-02	5.86E-02	4.50E-02	1.77E-02	1.73E-03	9.84E-04	6.66E-04
3	0.0	[illegible]	6.26E-02	5.41E-02	4.56E-02	3.70E-02	2.83E-02	2.37E-02	1.46E-02	1.00E-03	9.32E-04	6.51E-04
2	0.0	[illegible]	2.02E-02	2.02E-02	1.99E-02	1.97E-02	1.96E-02	1.95E-02	1.74E-02	5.91E-04	8.70E-04	6.42E-04
1	0.0	0.0	[illegible]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 18. 3-D Performance Model Output (Sheet 3 of 7).

J \ I =	13	14	15	16	17	18	19	20	21	22	23	24
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	7.80E-03	8.52E-03	1.54E-02	4.72E-38	8.37E-04	9.74E-04	1.01E-03	1.02E-03	1.03E-03	1.02E-03	1.01E-03	1.00E-03
17	6.86E-03	4.18E-03	1.21E-02	9.33E-03	6.28E-03	3.86E-03	2.42E-03	1.59E-03	1.10E-03	7.98E-04	6.07E-04	4.80E-04
16	6.30E-03	2.78E-03	7.75E-03	6.00E-03	4.34E-03	3.10E-03	2.24E-03	1.64E-03	1.22E-03	9.24E-04	7.09E-04	5.51E-04
15	5.84E-03	2.05E-03	4.99E-03	4.07E-03	3.15E-03	2.41E-03	1.84E-03	1.42E-03	1.11E-03	8.70E-04	6.90E-04	5.53E-04
14	5.40E-03	1.70E-03	3.23E-03	2.78E-03	2.27E-03	1.82E-03	1.46E-03	1.17E-03	9.45E-04	7.65E-04	6.23E-04	5.10E-04
13	4.86E-03	2.07E-03	2.10E-03	1.67E-03	1.60E-03	1.35E-03	1.12E-03	9.35E-04	7.77E-04	6.46E-04	5.39E-04	4.51E-04
12	4.08E-03	3.01E-03	1.86E-03	1.38E-03	1.14E-03	9.64E-04	8.24E-04	7.04E-04	6.01E-04	5.13E-04	4.38E-04	3.74E-04
11	2.98E-03	3.00E-03	2.68E-03	2.30E-03	1.44E-03	9.74E-04	7.17E-04	5.63E-04	4.62E-04	3.89E-04	3.33E-04	2.87E-04
10	1.99E-03	2.13E-03	2.06E-03	1.96E-03	1.75E-03	1.41E-03	8.37E-04	5.25E-04	3.51E-04	2.50E-04	1.89E-04	1.50E-04
9	2.89E-03	2.10E-03	1.16E-03	7.55E-04	5.65E-04	4.49E-04	3.66E-04	3.07E-04	2.59E-04	2.19E-04	1.87E-04	1.61E-04
8	3.69E-03	1.15E-03	1.39E-03	1.18E-03	9.88E-04	8.22E-04	6.83E-04	5.88E-04	5.25E-04	4.74E-04	4.27E-04	3.92E-04
7	4.20E-03	1.35E-03	2.22E-03	1.85E-03	1.51E-03	1.22E-03	9.93E-04	9.17E-04	9.10E-04	8.68E-04	7.97E-04	7.14E-04
6	4.62E-03	1.80E-03	3.29E-03	2.69E-03	2.12E-03	1.66E-03	1.32E-03	1.55E-03	1.81E-03	1.69E-03	1.46E-03	1.23E-03
5	4.96E-03	2.48E-03	4.81E-03	3.79E-03	2.87E-03	2.15E-03	1.68E-03	3.76E-03	4.99E-03	3.48E-03	2.50E-03	1.83E-03
4	5.25E-03	3.50E-03	7.14E-03	5.37E-03	3.82E-03	2.68E-03	1.89E-03	1.36E-03	9.99E-04	7.47E-04	5.68E-04	4.50E-04
3	5.51E-03	5.16E-03	1.08E-02	8.11E-03	5.32E-03	3.23E-03	1.99E-03	1.28E-03	8.61E-04	6.11E-04	4.53E-04	3.50E-04
2	5.40E-03	8.63E-03	1.68E-02	5.24E-38	4.87E-04	5.74E-04	6.02E-04	6.15E-04	6.20E-04	6.19E-04	6.16E-04	6.10E-04
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I =	25	26	27	28	29	30
19	0.0	0.0	0.0	0.0	0.0	0.0
18	9.86E-04	9.69E-04	9.51E-04	9.31E-04	8.92E-04	0.0
17	3.93E-04	3.31E-04	2.87E-04	2.55E-04	2.12E-04	0.0
16	4.34E-04	3.46E-04	2.80E-04	2.30E-04	1.78E-04	0.0
15	4.47E-04	3.64E-04	2.98E-04	2.46E-04	1.89E-04	0.0
14	4.19E-04	3.47E-04	2.89E-04	2.42E-04	1.89E-04	0.0
13	3.78E-04	3.18E-04	2.69E-04	2.28E-04	1.82E-04	0.0
12	3.20E-04	2.75E-04	2.36E-04	2.04E-04	1.66E-04	0.0
11	2.49E-04	2.17E-04	1.89E-04	1.66E-04	1.38E-04	0.0
10	1.23E-04	1.04E-04	8.97E-05	7.85E-05	6.65E-05	0.0
9	1.40E-04	1.23E-04	1.09E-04	9.81E-05	8.64E-05	0.0
8	3.41E-04	3.05E-04	2.73E-04	2.47E-04	2.15E-04	0.0
7	6.30E-04	5.51E-04	4.79E-04	4.16E-04	3.39E-04	0.0
6	1.02E-03	8.37E-04	6.88E-04	5.65E-04	4.27E-04	0.0
5	1.37E-03	1.03E-03	7.87E-04	6.05E-04	4.23E-04	0.0
4	3.66E-04	3.04E-04	2.54E-04	2.14E-04	1.67E-04	0.0
3	2.80E-04	2.32E-04	1.98E-04	1.72E-04	1.38E-04	0.0
2	6.02E-04	5.92E-04	5.82E-04	5.70E-04	5.45E-04	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0

FUEL MASS FRACTION

Figure 18. 3-D Performance Model Output (Sheet 4 of 7).

TEMPERATURE °K

K = 7

J \ I	1	2	3	4	5	6	7	8	9	10	11	12
19	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	5.89E+02	5.89E+02	5.89E+02
18	5.89E+02	8.74E+02	9.32E+02	9.48E+02	9.51E+02	9.54E+02	9.58E+02	9.62E+02	9.38E+02	5.89E+02	5.89E+02	5.88E+02
17	5.89E+02	1.48E+03	1.78E+03	1.97E+03	2.09E+03	2.09E+03	1.99E+03	1.77E+03	1.41E+03	6.19E+02	5.90E+02	5.88E+02
16	1.09E+03	1.81E+03	2.08E+03	2.30E+03	2.04E+03	2.22E+03	2.25E+03	2.12E+03	1.83E+03	6.77E+02	5.96E+02	5.88E+02
15	1.09E+03	1.70E+03	1.91E+03	2.23E+03	2.00E+03	2.00E+03	2.05E+03	2.27E+03	2.15E+03	7.54E+02	6.07E+02	5.89E+02
14	1.09E+03	1.63E+03	1.60E+03	1.93E+03	2.22E+03	2.38E+03	2.00E+03	2.16E+03	2.31E+03	8.41E+02	6.21E+02	5.91E+02
13	1.09E+03	1.57E+03	1.39E+03	1.33E+03	1.75E+03	2.20E+03	2.00E+03	2.09E+03	2.37E+03	8.89E+02	6.31E+02	5.93E+02
12	1.09E+03	1.49E+03	1.20E+03	1.19E+03	1.69E+03	2.22E+03	2.00E+03	2.14E+03	1.97E+03	8.75E+02	6.31E+02	5.94E+02
11	1.09E+03	1.37E+03	9.96E+02	1.45E+03	2.05E+03	2.09E+03	2.12E+03	1.74E+03	1.28E+03	8.03E+02	6.31E+02	5.96E+02
10	1.09E+03	1.46E+03	1.48E+03	1.91E+03	2.00E+03	2.16E+03	1.90E+03	1.53E+03	1.20E+03	8.39E+02	6.55E+02	6.04E+02
9	1.09E+03	1.31E+03	1.07E+03	1.36E+03	1.84E+03	2.16E+03	2.02E+03	2.12E+03	1.89E+03	9.67E+02	6.58E+02	6.01E+02
8	1.09E+03	1.40E+03	1.09E+03	1.38E+03	1.54E+03	2.07E+03	2.22E+03	2.02E+03	2.02E+03	9.90E+02	6.58E+02	5.98E+02
7	1.09E+03	1.44E+03	1.24E+03	1.16E+03	1.62E+03	2.07E+03	2.21E+03	2.30E+03	2.08E+03	9.56E+02	6.46E+02	5.95E+02
6	1.09E+03	1.46E+03	1.35E+03	1.53E+03	2.00E+03	2.14E+03	2.22E+03	2.30E+03	2.24E+03	8.57E+02	6.25E+02	5.92E+02
5	1.09E+03	1.48E+03	1.49E+03	2.00E+03	2.13E+03	2.20E+03	2.01E+03	2.01E+03	2.11E+03	7.62E+02	6.08E+02	5.90E+02
4	1.09E+03	1.56E+03	1.75E+03	2.01E+03	2.12E+03	2.00E+03	2.02E+03	2.13E+03	1.80E+03	6.77E+02	5.96E+02	5.89E+02
3	5.99E+02	1.42E+03	1.69E+03	1.89E+03	2.00E+03	2.02E+03	1.95E+03	1.80E+03	1.34E+03	6.15E+02	5.90E+02	5.89E+02
2	5.89E+02	8.65E+02	9.17E+02	9.29E+02	9.32E+02	9.34E+02	9.37E+02	9.40E+02	8.59E+02	5.89E+02	5.88E+02	5.89E+02
1	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	5.89E+02	5.89E+02	5.89E+02

J \ I	13	14	15	16	17	18	19	20	21	22	23	24
19	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03
18	7.59E+02	9.47E+02	9.98E+02	5.89E+02	6.75E+02	7.04E+02	7.21E+02	7.37E+02	7.52E+02	7.67E+02	7.82E+02	7.98E+02
17	7.52E+02	1.07E+03	1.04E+03	1.10E+03	1.17E+03	1.25E+03	1.30E+03	1.33E+03	1.34E+03	1.34E+03	1.34E+03	1.34E+03
16	7.46E+02	1.12E+03	1.13E+03	1.18E+03	1.24E+03	1.29E+03	1.34E+03	1.38E+03	1.42E+03	1.44E+03	1.46E+03	1.47E+03
15	7.37E+02	1.15E+03	1.21E+03	1.25E+03	1.29E+03	1.34E+03	1.38E+03	1.41E+03	1.45E+03	1.48E+03	1.50E+03	1.51E+03
14	7.23E+02	1.14E+03	1.26E+03	1.30E+03	1.34E+03	1.37E+03	1.41E+03	1.44E+03	1.47E+03	1.49E+03	1.51E+03	1.53E+03
13	7.04E+02	1.04E+03	1.28E+03	1.34E+03	1.37E+03	1.40E+03	1.43E+03	1.46E+03	1.48E+03	1.50E+03	1.52E+03	1.53E+03
12	6.78E+02	8.75E+02	1.11E+03	1.26E+03	1.34E+03	1.39E+03	1.42E+03	1.45E+03	1.47E+03	1.49E+03	1.51E+03	1.52E+03
11	6.41E+02	7.25E+02	8.37E+02	9.55E+02	1.08E+03	1.18E+03	1.26E+03	1.32E+03	1.37E+03	1.41E+03	1.44E+03	1.47E+03
10	6.56E+02	7.24E+02	7.96E+02	8.69E+02	9.41E+02	1.01E+03	1.08E+03	1.15E+03	1.21E+03	1.26E+03	1.30E+03	1.34E+03
9	7.12E+02	9.10E+02	1.12E+03	1.27E+03	1.36E+03	1.41E+03	1.45E+03	1.48E+03	1.49E+03	1.50E+03	1.50E+03	1.51E+03
8	7.54E+02	1.14E+03	1.39E+03	1.44E+03	1.49E+03	1.51E+03	1.54E+03	1.56E+03	1.58E+03	1.59E+03	1.60E+03	1.61E+03
7	7.81E+02	1.19E+03	1.35E+03	1.40E+03	1.45E+03	1.49E+03	1.52E+03	1.55E+03	1.58E+03	1.60E+03	1.62E+03	1.64E+03
6	7.74E+02	1.15E+03	1.30E+03	1.36E+03	1.41E+03	1.46E+03	1.51E+03	1.55E+03	1.59E+03	1.62E+03	1.65E+03	1.67E+03
5	7.65E+02	1.13E+03	1.26E+03	1.32E+03	1.38E+03	1.44E+03	1.49E+03	1.54E+03	1.59E+03	1.63E+03	1.66E+03	1.68E+03
4	7.57E+02	1.11E+03	1.21E+03	1.27E+03	1.36E+03	1.41E+03	1.47E+03	1.52E+03	1.55E+03	1.57E+03	1.58E+03	1.59E+03
3	7.50E+02	1.04E+03	1.16E+03	1.21E+03	1.29E+03	1.38E+03	1.43E+03	1.45E+03	1.45E+03	1.44E+03	1.43E+03	1.42E+03
2	7.47E+02	9.78E+02	1.10E+03	5.89E+02	6.61E+02	6.87E+02	7.05E+02	7.21E+02	7.38E+02	7.54E+02	7.71E+02	7.88E+02
1	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03

Figure 18. 3-D Performance Model Output (Sheet 5 of 7).

TEMPERATURE °K

J	I = 25	26	27	28	29	30
19	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03
18	8.13E+02	9.27E+02	8.41E+02	8.55E+02	8.79E+02	1.32E+03
17	1.34E+03	1.33E+03	1.33E+03	1.32E+03	1.31E+03	1.32E+03
16	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.47E+03	1.32E+03
15	1.52E+03	1.53E+03	1.53E+03	1.54E+03	1.53E+03	1.32E+03
14	1.54E+03	1.55E+03	1.55E+03	1.56E+03	1.56E+03	1.32E+03
13	1.54E+03	1.55E+03	1.56E+03	1.56E+03	1.57E+03	1.32E+03
12	1.53E+03	1.54E+03	1.55E+03	1.56E+03	1.56E+03	1.32E+03
11	1.48E+03	1.50E+03	1.51E+03	1.52E+03	1.53E+03	1.32E+03
10	1.37E+03	1.40E+03	1.43E+03	1.45E+03	1.47E+03	1.32E+03
9	1.52E+03	1.52E+03	1.53E+03	1.53E+03	1.55E+03	1.32E+03
8	1.62E+03	1.63E+03	1.64E+03	1.65E+03	1.66E+03	1.32E+03
7	1.66E+03	1.67E+03	1.68E+03	1.69E+03	1.70E+03	1.32E+03
6	1.69E+03	1.70E+03	1.71E+03	1.72E+03	1.72E+03	1.32E+03
5	1.69E+03	1.69E+03	1.70E+03	1.70E+03	1.69E+03	1.32E+03
4	1.59E+03	1.59E+03	1.59E+03	1.59E+03	1.57E+03	1.32E+03
3	1.41E+03	1.40E+03	1.39E+03	1.38E+03	1.37E+03	1.32E+03
2	8.05E+02	8.21E+02	8.37E+02	8.53E+02	8.79E+02	1.32E+03
1	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03

K = 7

J	I = 1	2	3	4	5	6	7	8	9	10	11	12
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.36E-07	1.02E-06	5.77E-07	2.48E-05
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.50E-07	3.95E-07	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	1.11E-06	5.59E-07	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	1.09E-06	5.32E-07	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	1.16E-06	9.09E-07	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	5.23E-06	2.65E-06	0.0	0.0	0.0	0.0	0.0	1.53E-08	0.0
12	0.0	0.0	2.57E-06	7.29E-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	4.70E-06	1.78E-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	4.55E-06	1.86E-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	2.46E-06	7.14E-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	5.17E-06	8.75E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	1.69E-06	9.16E-07	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	1.12E-06	8.69E-07	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	1.11E-06	5.82E-07	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.05E-07	3.21E-07	0.0	5.94E-08	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.70E-07	7.03E-07	1.06E-06	7.66E-07
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

EVAPORATION RATE (KG/SEC)

Figure 18. 3-D Performance Model Output (Sheet 6 of 7).

J \ I =	13	14	15	16	17	18	19	20	21	22	23	24
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	8.35E-07	2.38E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.97E-07	2.67E-07	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.92E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4.56E-07	2.06E-07	1.76E-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I =	25	26	27	28	29	30
19	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0

EVAPORATION RATE (KG/SEC)

Figure 18. 3-D Performance Model Output (Sheet 7 of 7).

by I = 15 with a few larger droplets persisting at I = 20, where they entered from neighboring K-planes.

LINER-COOLING MODEL.

The liner-cooling model was used to predict the wall temperatures downstream of the cooling slots in the combustor shown in Figure 15. Starting with the profiles at the exit of the slot, as predicted by the 3-D performance model, the program marched up to the beginning of the transition liner. At each marching step, the program performed a heat-flux balance at the wall and, thereby, obtained the wall temperature.

The input units, required by the liner-cooling model, are S.I., and since these are the output units of the 3-D performance model, data is easily transferred. Profiles for U-velocity, temperature, turbulent kinetic energy, turbulence length scale, fuel-mass fraction, total fuel, and CO are required along with information about the flow conditions in the inner and outer annuli. Since nearly all the liquid fuel has evaporated at the point where the marching process begins, no input for the droplet evaporation is needed.

The input data sheets (Figure 19, 3 sheets) begin with two cards devoted to case identification (additonal input information can be found in the input sheet forms located in Appendix A). Next, 40 cross stream grid cells are specified. It was unlikely that this would be sufficient to obtain a grid-independent solution; however, since this was merely an example case, the maximum dimension allowed in the existing deck was selected. Axisymmetric geometry, solve species equations, two-equation turbulence model, reacting species, wall temperature, and enthalpy calculation completed the specifications on Card 2. Card 3 indicates that the various profiles will be printed every 20 marching steps. On Card 4 one sees that the marching process will start at

CASE TITLE (12A6)

1								
	LINER COOLING	MODEL	EXAMPLE	CASE				

CASE TITLE (12A6)

KPLANE	= 7						

(8(I2, 8X)

	N	KRAD	MASSTR	ISWRL	MODEL	INERT	IFLUX	ITEMP
2	40	01	01	00	02	02	01	01

(5(I5,5X)

	NSTAT	NPROF	NPLOT	ITEST	LASTEP			
3	99999	00020	99999		99999			

(8E10.4)

	XU	XULAST	FRA	XEND	XOUT	PRESS	POWER	
4	.03937	.073	.02	10.	10.	101325	2.0	

(I2)

	NBP							
5	02							

(8E10.4)

	X_1	RI_1	RE_1	X_2	RI_2	RE_2	X_3	RI_3
6	0.	.254	.29972	10.	.254	.29972		

(8E10.4)

RE_3	X_4	RI_4	RE_4	X_5	RI_5	RE_5...	

(8E10.4)

	RA	RB	RD					
7	0.	.254	.29972					

Figure 19. Liner Cooling Model Input Sheet (1 of 3)

NAME LIST

Card								
8	$INPUT	KREAD	=1, PRE	XP1=3.3	E+14,	ARCON1=	27000,	$

CRI=3.0, CX=10, MY=19.28

UA UD (8E10.4)

Card								
9	0.	0.						

F2A F2D TA TD T_{wall} (8E10.4)

Card								
10	0.	0.	589.	589.	589.			

NIN (I2)

Card								
11	19							

Y VALUES (8E10.4)

Card								
12								

U VALUES (8E10.4)

Card								
13								

(8E10.4)

Card								
14								

TEMPERATURE VALUES (8E10.4)

Card								
15								

MFU VALUES (8E10.4)

Card								
16								

PHI VALUES (8E10.4)

Card								
17								

Figure 19. Liner Cooling Model Input Sheet (2 of 3)

MCO VALUES (8E10.4)

18								

TURBULENT KINETIC ENERGY (8E10.4)

19								

TURBULENCE LENGTH SCALE (8E10.4)

20								

	$VELA_I$	$VELA_O$	TAN_I	TAN_O	PR_I	PR_O	(8E10.4)	
21	24.7	58.8	589.	589.	.2413	.3124		

(I2, 8X, 7E10.4)

	NFNZ	XDP	YDP	UF	VF	SMD	WF	TFUEL
22	00							

Figure 19. Liner Cooling Model Input Sheet (3 of 3)

0.03937 meter and proceed to 0.073 meter, using a step size of 0.02 times the grid height. In order to obtain the best estimation of the radiation flux, it is necessary to analyze the entire channel height, which means the inner and outer boundaries are walls. XEND and XOUT are, therefore, set to some large number. The variable POWER is used to distort the grid, since more nodes are required near the wall whose temperature is being predicted. This means, of course, that two runs must be made, one with the grid nodes concentrated near the outer wall (POWER <-1.0), and one with the nodes concentrated near the inner wall (POWER >1.0). If POWER equals 1.0 or -1.0, the resulting grid would be uniform in y.

Two straight walls require only two boundary point specifications, handled by Cards 5 and 6. The three radii specified on Card 7 are also easily understood. The name list is read next with the variables specified explained in the name list input sheet. The values on Cards 9 and 10 pertain to the free boundaries, which are not used on this program; however, entries are made for completeness. Cards 11 through 20 specify the initial profiles. The 19 points used correspond to the 19 radial nodes used by the 3-D performance model and are listed in Table 1. For this example the 3-D output was strictly used; however, it is usually the practice to combine the 3-D profiles with some additional information, if available, describing the profiles inside the slot lip. Card 21 lists data concerning the annulus flow conditions and dimensions while Card 22 is blank due to the absence of liquid fuel.

The output from the program is shown in Figure 20 (3 sheets). Sheet 1 begins with the titles, some control indices, and the values of omega for the transformed cross-stream variable. Information about the annuli is printed next along with the initial profiles. The printing of the variable arrays starts with the value at the inner boundary and continues outward.

TABLE 1. INITIAL PROFILES FOR LINER COOLING EXAMPLE.

Node	Y	U	KE	lm	ϕ	MFU	MCO	TEMP
19	0.04572	45.7	6.27	7.62E-5	0	0	0	589
18	0.04318	45.7	6.27	7.62E-5	0	0	0	589
17	0.04064	26.1	13.5	2.86E-4	0.0273	7.8E-3	0.0190	1135
16	0.03810	28.2	51.9	3.68E-4	0.0270	5.17E-3	0.0205	1210
15	0.03556	25.5	65.7	4.22E-4	0.0270	3.61E-3	0.0198	1270
14	0.03302	22.2	71.7	4.76E-4	0.0269	2.53E-3	0.0182	1320
13	0.03048	20.3	73.3	4.81E-4	0.0265	1.73E-3	0.0158	1355
12	0.02794	21.8	77.5	4.66E-4	0.0239	1.26E-3	0.0141	1300
11	0.02540	40.6	126	3.11E-4	0.0154	1.87E-3	0.00976	1018
10	0.02286	53.4	277	2.74E-4	0.0117	1.86E-3	0.00713	905
9	0.02032	21.0	123	4.72E-4	0.0233	6.6E-4	0.0120	1315
8	0.01778	15.3	83.3	5.17E-4	0.0283	1.08E-3	0.0129	1460
7	0.01524	16.2	76.8	4.87E-4	0.0288	1.68E-3	0.0166	1425
6	0.01270	19.2	71.5	4.52E-4	0.0291	2.41E-3	0.0195	1385
5	0.01016	23.0	65.5	4.15E-4	0.0294	3.33E-3	0.0215	1350
4	0.00762	25.9	52.3	3.62E-4	0.0298	4.60E-3	0.0228	1305
3	0.00508	24.1	12.9	2.87E-4	0.0302	6.72E-3	0.0227	1250
2	0.00254	45.7	6.27	7.62E-5	0	0	0	589
1	0.0000	45.7	6.27	7.62E-5	0	0	0	589

U-Values are for K = 7, I = 17 and the avg. of I = 16 and 17. Other Values are for K = 7

```
XYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXY
XYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXY

LINER COOLING MODEL EXAMPLE CASE
NPLANE=7 I.D. WALL
MODER=  2 ICPDX=  1 MODEL=  2 MASSTR=  1 INERT=  2 KRAD=  1 IFLUX=  1
UA        UD        TA        TD        PA        PB        PD        XEND      XOUT      XJLAST
0.        0.        5.890E+02 5.890E+02 0.        2.540E-01 2.997E-01 1.000E+01 1.000E+01 7.330E-02
PRESS     PREXPI    ARCONI    CP1       VTA       VTD
1.013E+05 3.300E+14 2.700E+04 3.000E+00-0.        -0.

OMEGA     0.        0.        1.486E-03 5.944E-03 1.338E-02 2.379E-02 3.719E-02 5.359E-02 7.300E-02 9.542E-02 1.209E-01
          1.469E-01 1.692E-01 1.866E-01 1.998E-01 2.107E-01 2.217E-01 2.336E-01 2.462E-01 2.590E-01 2.717E-01 2.842E-01
          2.961E-01 3.076E-01 3.186E-01 3.292E-01 3.450E-01 3.576E-01 3.772E-01 4.126E-01 4.739E-01 5.241E-01 5.604E-01
          5.845E-01 6.062E-01 6.293E-01 6.562E-01 6.880E-01 7.249E-01 7.688E-01 8.620E-01 1.000E+00 1.000E+00

  BOUNDRY     VELA      TAN       PRAD
  ********  ********  ********  ********
     I      2.470E+01 5.890E+02 2.413E-01
     E      5.280E+01 5.890E+02 3.124E-01

ISTEP=    3 IAX=10000 IEND=10000 IOUT=10000 KIN= 1 KEX= 1 DX=  1.372E-05 PSII=  0.        PSIE=  1.332E-01
RMI=  0.          RME=  0.          PEI=  1.332E-01 PRESSD=  0.          AFFD=  0.
XU=  3.937E-02 UFLUX=  4.660E+00 FLUX(J)= -3.181E+03 2.741E-04 3.355E-03 1.327E-03 2.534E-02 2.145E-03 0.        0.
                                        0.        0.        0.        0.        0.        *.110E+30 2.455E+04 1.998E-03
KIN= 1 TAUID=  2.649E-01 AJID(J)=  8.906E-03 0.        0.        0.        0.        0.        0.        0.
                                   0.        0.        0.        0.        0.        0.        -2.929E-02 0.
KEX= 1 TAUED=  1.543E-02 AJED(J)= -6.163E-04 0.        0.        0.        0.        0.        0.        0.
                                   0.        0.        0.        0.        0.        0.        1.390E-03 0.

R1,Y'S    2.540E-01 0.        2.858E-05 1.143E-04 2.572E-04 4.572E-04 7.144E-04 1.029E-03 1.400E-03 1.829E-03 2.315E-03
          2.857E-03 3.458E-03 4.115E-03 4.829E-03 5.601E-03 6.429E-03 7.315E-03 8.258E-03 9.258E-03 1.032E-02 1.143E-02
          1.260E-02 1.383E-02 1.512E-02 1.646E-02 1.786E-02 1.932E-02 2.083E-02 2.240E-02 2.403E-02 2.572E-02 2.746E-02
          2.926E-02 3.112E-02 3.303E-02 3.500E-02 3.703E-02 3.912E-02 4.126E-02 4.346E-02 4.572E-02 4.572E-02

U         0.        4.570E+01 4.570E+01 4.570E+01 4.570E+01 4.570E+01 4.570E+01 4.570E+01 4.570E+01 4.570E+01 4.570E+01
          4.300E+01 3.790E+01 3.231E+01 2.623E+01 2.447E+01 2.506E+01 2.569E+01 2.517E+01 2.403E+01 2.277E+01 2.110E+01
          1.935E+01 1.786E+01 1.635E+01 1.577E+01 1.548E+01 1.875E+01 2.752E+01 4.757E+01 4.750E+01 3.825E+01 2.535E+01
          2.102E+01 2.078E+01 2.222E+01 2.478E+01 2.707E+01 2.735E+01 3.090E+01 4.570E+01 4.570E+01 0.

FUEL      0.        0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
          6.400E-04 2.428E-03 4.166E-03 6.056E-03 6.285E-03 5.594E-03 4.854E-03 4.291E-03 3.791E-03 3.274E-03 2.870E-03
          2.446E-03 2.085E-03 1.716E-03 1.392E-03 1.067E-03 8.259E-04 9.015E-04 1.644E-03 1.965E-03 1.794E-03 1.375E-03
          1.504E-03 1.931E-03 2.535E-03 3.374E-03 4.515E-03 6.225E-03 5.889E-03 0.        0.        0.

CO        0.        0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
          2.838E-03 8.200E-03 1.407E-02 2.046E-02 2.272E-02 2.275E-02 2.279E-02 2.247E-02 2.196E-02 2.136E-02 2.056E-02
          1.958E-02 1.821E-02 1.674E-02 1.482E-02 1.287E-02 1.236E-02 1.102E-02 8.007E-03 8.343E-03 1.030E-02 1.326E-02
          1.498E-02 1.640E-02 1.821E-02 1.945E-02 2.021E-02 1.990E-02 1.434E-02 0.        0.        0.

OXYGEN    2.320E-01 2.320E-01 2.320E-01 2.320E-01 2.320E-01 2.320E-01 2.320E-01 2.320E-01 2.320E-01 2.320E-01 2.320E-01
          2.228E-01 2.053E-01 1.861E-01 1.653E-01 1.568E-01 1.550E-01 1.530E-01 1.514E-01 1.500E-01 1.485E-01 1.471E-01
          1.456E-01 1.442E-01 1.426E-01 1.413E-01 1.406E-01 1.499E-01 1.651E-01 1.920E-01 1.944E-01 1.641E-01 1.632E-01
          1.538E-01 1.512E-01 1.532E-01 1.565E-01 1.607E-01 1.659E-01 1.853E-01 2.320E-01 2.320E-01 2.320E-01

KE        0.        6.270E+00 6.270E+00 6.270E+00 6.270E+00 6.270E+00 6.270E+00 6.270E+00 6.270E+00 6.270E+00 6.270E+00
          7.099E+00 8.665E+00 1.038E+01 1.225E+01 2.098E+01 3.383E+01 4.757E+01 5.562E+01 6.031E+01 6.587E+01 6.850E+01
          7.127E+01 7.386E+01 7.654E+01 7.992E+01 8.456E+01 1.073E+02 1.540E+02 2.493E+02 2.074E+02 1.199E+02 8.665E+01
          7.532E+01 7.290E+01 7.167E+01 6.701E+01 5.770E+01 3.649E+01 1.173E+01 6.270E+00 6.270E+00 0.

LEN       0.        7.620E-05 7.620E-05 7.620E-05 7.620E-05 7.620E-05 7.620E-05 7.620E-05 7.620E-05 7.620E-05 7.620E-05
          1.026E-04 1.524E-04 2.369E-04 2.662E-04 3.074E-04 3.289E-04 3.530E-04 3.753E-04 3.967E-04 4.173E-04 4.335E-04
          4.506E-04 4.676E-04 4.853E-04 5.014E-04 5.156E-04 4.898E-04 4.322E-04 3.096E-04 2.911E-04 3.304E-04 4.367E-04
          4.738E-04 4.797E-04 4.757E-04 4.338E-04 3.907E-04 3.351E-04 2.346E-04 7.620E-05 7.620E-05 0.
```

Figure 20. Liner Cooling Model Output (Sheet 1 of 3).

PHI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	3.775E-03	1.091E-02	1.872E-02	2.722E-02	3.012E-02	2.999E-02	2.985E-02	2.970E-02	2.954E-02	2.939E-02	2.925E-02
	2.911E-02	2.897E-02	2.881E-02	2.856E-02	2.914E-02	2.577E-02	2.097E-02	1.379E-02	1.341E-02	1.646E-02	2.230E-02
	2.525E-02	2.660E-02	2.690E-02	2.698E-02	2.700E-02	2.712E-02	2.061E-02	0.	0.	0.	
TEMP	5.890E+02	5.890E+02	5.890E+02	5.890E+02	5.890E+02	5.890E+02	5.890E+02	5.890E+02	5.890E+02	5.890E+02	5.890E+02
	6.716E+02	8.279E+02	9.988E+02	1.155E+03	1.261E+03	1.279E+03	1.298E+03	1.316E+03	1.334E+03	1.352E+03	1.367E+03
	1.384E+03	1.403E+03	1.423E+03	1.442E+03	1.455E+03	1.372E+03	1.232E+03	9.788E+02	9.571E+02	1.053E+03	1.247E+03
	1.329E+03	1.346E+03	1.320E+03	1.281E+03	1.235E+03	1.180E+03	1.001E+03	5.890E+02	5.890E+02	5.890E+02	
RAD	6.824E+03	6.824E+03	6.824E+03	6.824E+03	6.824E+03	6.824E+03	6.824E+03	6.824E+03	6.824E+03	6.824E+03	6.824E+03
	1.154E+04	2.662E+04	5.643E+04	1.117E+05	1.435E+05	1.518E+05	1.611E+05	1.702E+05	1.796E+05	1.895E+05	1.983E+05
	2.078E+05	2.196E+05	2.325E+05	2.450E+05	2.544E+05	2.011E+05	1.308E+05	5.204E+04	4.758E+04	6.976E+04	1.370E+05
	1.767E+05	1.862E+05	1.720E+05	1.526E+05	1.320E+05	1.099E+05	5.698E+04	6.824E+03	6.824E+03	6.824E+03	
AMU(I)	3.063E-05	5.958E-05	5.958E-05	5.958E-05	5.958E-05	5.958E-05	5.958E-05	5.958E-05	5.958E-05	5.958E-05	5.958E-05
	7.342E-05	9.615E-05	1.183E-04	1.398E-04	2.041E-04	2.968E-04	3.989E-04	4.680E-04	5.714E-04	5.754E-04	6.099E-04
	6.454E-04	6.804E-04	7.156E-04	7.533E-04	7.988E-04	9.635E-04	1.168E-03	1.415E-03	1.212E-03	9.912E-04	8.162E-04
	7.572E-04	7.394E-04	7.437E-04	6.611E-04	5.536E-04	3.818E-04	1.448E-04	5.958E-05	5.958E-05	3.063E-05	
TEMP	9.051E+02	6.616E+02	7.593E+02	5.552E+02	4.944E+02	5.912E+02	5.692E+02	5.890E+02	5.893E+02	5.694E+02	6.002E+02
	6.881E+02	8.453E+02	1.039E+03	1.322E+03	1.493E+03	1.559E+03	1.569E+03	1.577E+03	1.593E+03	1.580E+03	1.591E+03
	1.592E+03	1.589E+03	1.575E+03	1.541E+03	1.481E+03	1.388E+03	1.256E+03	1.068E+03	1.008E+03	1.099E+03	1.288E+03
	1.418E+03	1.494E+03	1.496E+03	1.462E+03	1.444E+03	1.345E+03	1.017E+03	5.954E+02	5.073E+02	9.539E+02	
RAD	6.824E+03	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05
	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05
	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05
	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	1.595E+05	6.824E+03	
AMU(I)	4.029E-05	4.228E-05	4.601E-05	4.718E-05	3.713E-05	4.380E-05	5.549E-05	5.766E-05	5.472E-05	5.608E-05	5.950E-05
	7.876E-05	1.146E-04	1.449E-04	1.429E-04	1.688E-04	2.261E-04	2.644E-04	3.413E-04	3.325E-04	4.351E-04	4.794E-04
	5.196E-04	5.655E-04	6.276E-04	[illegible]	2.239E-04	2.347E-04	1.178E-03	1.709E-03	1.095E-03	9.554E-04	6.249E-04
	6.916E-04	6.238E-04	5.847E-04	[illegible]	4.193E-04	2.863E-04	1.626E-04	5.998E-05	2.333E-04	4.136E-05	

Figure 20. Liner Cooling Model Output (Sheet 2 of 3).

```
ISTEP=   80 IAX=10000 IEND=10000 IOUT=10000 KIN= 1 KEX= 1 DX=   9.138E-04 PSII=   0.            PSIE=   1.332E-01
RMI=  0.            RME=  0.           PEI=   1.332E-01 PRESSD= -2.088E-04 AEXD= -6.509E-04
XU=  7.068E-02 UFLUX=   4.877E+00 FLUX(J)= -2.402E+03   9.087E-05   5.380E-03   4.109E-04   2.418E-02   2.376E-03  0.          0.
                                            0.          0.          0.          0.          0.          2.934E+00   3.125E+03  1.998E-03
KIN= 1 TAUID=   1.146E-02 AJID(J)= -1.119E-02   0.          0.          0.          0.          0.          0.          0.
                                            0.          0.          0.          0.          0.          0.          -5.557E-01  0.
KEX= 1 TAUED=   9.954E-03 AJED(J)=   9.575E-03   0.          0.          0.          0.          0.          0.          0.
                                            0.          0.          0.          0.          0.          0.          7.202E-04   0.

P1,Y'S      2.540E-01  5.447E-05  1.741E-04  3.965E-04  6.630E-04  9.970E-04  1.157E-03  1.468E-03  1.834E-03  2.256E-03  2.750E-03
            3.323E-03  3.959E-03  4.642E-03  5.357E-03  6.111E-03  6.953E-03  7.939E-03  8.987E-03  1.007E-02  1.119E-02  1.231E-02
            1.341E-02  1.447E-02  1.545E-02  1.632E-02  1.712E-02  1.795E-02  1.905E-02  2.084E-02  2.297E-02  2.496E-02  2.654E-02
            2.806E-02  2.955E-02  3.127E-02  3.327E-02  3.550E-02  3.784E-02  4.006E-02  4.228E-02  4.487E-02  4.569E-02

U           0.         5.792E+00  1.854E+01  2.718E+01  3.617E+01  4.366E+01  4.603E+01  4.644E+01  4.649E+01  4.641E+01  4.579E+01
            4.295E+01  3.971E+01  3.468E+01  3.142E+01  2.952E+01  2.875E+01  2.836E+01  2.784E+01  2.708E+01  2.611E+01  2.511E+01
            2.437E+01  2.423E+01  2.498E+01  2.651E+01  2.853E+01  3.107E+01  3.487E+01  4.095E+01  4.321E+01  3.880E+01  3.305E+01
            2.917E+01  2.700E+01  2.674E+01  2.792E+01  2.950E+01  3.057E+01  3.329E+01  4.604E+01  4.279E+01  0.

FUEL        5.830E-10  5.242E-10  6.418E-10  1.094E-09  3.056E-09  1.544E-08  1.017E-07  7.031E-07  5.143E-06  3.677E-05  2.671E-04
            1.157E-03  2.121E-03  1.972E-03  7.433E-04  3.571E-04  2.201E-04  1.580E-04  1.224E-04  9.750E-05  7.666E-05  6.310E-05
            5.069E-05  4.217E-05  4.024E-05  4.833E-05  6.971E-05  1.152E-04  2.390E-04  8.015E-04  1.237E-03  7.746E-04  2.534E-04
            1.101E-04  7.157E-05  7.826E-05  1.092E-04  1.854E-04  5.583E-04  4.773E-03  1.855E-04  5.216E-06  9.585E-05

CO          1.963E-09  1.762E-09  2.164E-09  3.696E-09  1.033E-08  5.220E-08  3.440E-07  2.380E-06  1.743E-05  1.316E-04  9.145E-04
            4.046E-03  7.949E-03  9.076E-03  5.015E-03  2.659E-03  1.697E-03  1.237E-03  9.710E-04  7.815E-04  6.303E-04  5.098E-04
            4.264E-04  4.007E-04  4.733E-04  6.936E-04  1.120E-03  1.945E-03  3.529E-03  6.212E-03  7.399E-03  6.720E-03  3.693E-03
            1.556E-03  8.903E-04  8.402E-04  1.143E-03  1.856E-03  3.687E-03  1.192E-02  4.593E-04  1.534E-05  2.373E-04

OXYGEN      2.320E-01  2.320E-01  2.320E-01  2.320E-01  2.320E-01  2.320E-01  2.320E-01  2.320E-01  2.319E-01  2.316E-01  2.290E-01
            2.180E-01  2.002E-01  1.777E-01  1.516E-01  1.350E-01  1.283E-01  1.261E-01  1.255E-01  1.254E-01  1.261E-01  1.270E-01
            1.287E-01  1.317E-01  1.361E-01  1.414E-01  1.469E-01  1.532E-01  1.618E-01  1.755E-01  1.519E-01  1.737E-01  1.600E-01
            1.496E-01  1.418E-01  1.372E-01  1.356E-01  1.361E-01  1.415E-01  1.619E-01  2.303E-01  2.319E-01  2.311E-01

KE          0.         1.435E+01  4.064E+01  3.529E+01  1.531E+01  3.726E+00  2.676E+00  2.021E+00  2.043E+00  2.086E+00  2.480E+00
            4.627E+00  8.419E+00  1.011E+01  9.900E+00  1.066E+01  1.248E+01  1.506E+01  1.743E+01  1.934E+01  2.079E+01  2.194E+01
            2.346E+01  2.677E+01  3.313E+01  4.186E+01  5.088E+01  5.937E+01  6.641E+01  6.266E+01  5.291E+01  5.221E+01  4.625E+01
            3.592E+01  2.749E+01  2.369E+01  2.229E+01  1.924E+01  1.390E+01  8.518E+00  2.437E+00  3.993E+00  0.

LEN         0.         1.551E-05  7.285E-05  9.132E-05  7.673E-05  5.650E-05  8.362E-05  1.182E-04  1.250E-04  1.265E-04  1.367E-04
            1.848E-04  2.549E-04  3.135E-04  3.730E-04  4.472E-04  5.197E-04  5.737E-04  6.192E-04  6.621E-04  7.045E-04  7.483E-04
            7.884E-04  8.021E-04  7.802E-04  7.489E-04  7.230E-04  6.992E-04  6.676E-04  6.113E-04  5.789E-04  6.013E-04  6.562E-04
            7.099E-04  7.593E-04  7.594E-04  7.062E-04  6.294E-04  5.259E-04  3.653E-04  1.375E-04  5.919E-04  0.

PHI         2.623E-09  2.358E-09  2.897E-09  4.924E-09  1.375E-08  6.951E-08  4.582E-07  3.171E-06  2.326E-05  1.762E-04  1.231E-03
            5.565E-03  1.197E-02  1.320E-02  2.352E-02  2.715E-02  2.886E-02  2.945E-02  2.955E-02  2.947E-02  2.930E-02  2.902E-02
            2.852E-02  2.768E-02  2.648E-02  2.506E-02  2.364E-02  2.208E-02  2.008E-02  1.727E-02  1.610E-02  1.781E-02  2.061E-02
            2.302E-02  2.501E-02  2.627E-02  2.680E-02  2.693E-02  2.599E-02  2.014E-02  7.075E-04  2.314E-05  3.653E-04

TEMP        3.580E+02  9.278E+02  8.172E+02  7.431E+02  6.696E+02  6.105E+02  5.925E+02  5.895E+02  5.896E+02  5.930E+02  6.171E+02
            7.181E+02  8.861E+02  1.107E+03  1.373E+03  1.525E+03  1.592E+03  1.618E+03  1.624E+03  1.624E+03  1.620E+03  1.613E+03
            1.598E+03  1.571E+03  1.532E+03  1.485E+03  1.433E+03  1.374E+03  1.289E+03  1.150E+03  1.086E+03  1.168E+03  1.307E+03
            1.410E+03  1.481E+03  1.522E+03  1.555E+03  1.527E+03  1.471E+03  1.048E+03  6.061E+02  5.266E+02  9.830E+02

RAD         6.824E+03  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05
            1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05
            1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05
            1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  1.682E+05  6.824E+03

AMU(I)      4.145E-05  5.374E-05  1.010E-04  1.332E-04  8.007E-05  4.258E-05  4.450E-05  5.419E-05  5.664E-05  5.740E-05  6.366E-05
            9.836E-05  1.530E-04  1.639E-04  1.526E-04  1.706E-04  2.128E-04  2.636E-04  3.162E-04  3.581E-04  4.190E-04  4.722E-04
            5.344E-04  6.092E-04  6.985E-04  8.040E-04  9.127E-04  1.071E-03  1.125E-03  1.133E-03  1.035E-03  9.729E-04  8.631E-04
            7.327E-04  6.280E-04  5.524E-04  4.751E-04  3.750E-04  2.548E-04  1.906E-04  6.431E-05  2.790E-05  4.199E-05

ISTEP=   83 IAX=10000 IEND=10000 IOUT=10000 KIN= 1 KEX= 1 DX=   0.           PSII=   0.            PSIE=   1.332E-01
RMI=  0.            RME=  0.           PEI=   1.332E-01 PRESSD= -2.117E-04 AEXD= -7.709E-04
XU=  7.300E-02 UFLUX=   4.875E+00 FLUX(J)= -2.350E+03   9.758E-05   5.419E-03   3.925E-04   2.416E-02   2.390E-03  0.          0.
                                            0.          0.          0.          0.          0.          2.885E+00   2.926E+03  1.992E-03
KIN= 1 TAUID=   1.146E-02 AJID(J)= -1.114E-02   0.          0.          0.          0.          0.          0.          0.
                                            0.          0.          0.          0.          0.          0.          -7.263E-01  0.
KEX= 1 TAUED=   9.864E-03 AJED(J)=   9.610E-03   0.          0.          0.          0.          0.          0.
                                            0.          0.          0.          0.
```

Figure 20. Liner Cooling Model Output (Sheet 3 of 3).

Since y is always referenced from the inner boundary, y(1) is always zero, so the radius of the inner boundary is printed in its place. It can also be seen that the y values are more closely spaced near the inner boundary, since this was the wall temperature that was calculated during this run. Sheets 2 and 3 of Figure 20 show a printout after 80 marching steps as indicated by ISTEP. The program has traversed to an X-location (XU) of 0.0706 meter, which is very near the end of the combustor. At this position the inner-wall temperature is 958°K. The other profiles are also printed with KE being the turbulent kinetic energy, LEN the turbulence length scale, PHI the total fuel, RAD the radiation-composite flux, and AMU(I) the effective viscosity. It should be noted that the boundary values of the radiation-composite flux are never used and are therefore left at their initial values.

TRANSITION MIXING MODEL

The 3-D performance model was used to predict the flow field up to the end of the combustor liner (Figure 15), but it is not capable of handling the geometric configuration of the transition liner. For that, the transition-mixing model (TMM) is used. Using initial profiles as predicted by the 3-D program, the TMM marches through the transition liner, thereby predicting the temperature distribution at what would be the turbine-stator inlet.

An enlarged drawing of the transition liner is shown in Figure 21. The inlet and exit planes are marked along with several intermediate ones. The location of these is a matter of user choice, but should be enough to simulate the actual liner-wall geometry. The radius of curvature is constant. In this case it is 0.5 inch for the inner wall and 1.9 inches for the outer wall. The input sheets are shown in Figure 22 (3 sheets). (Additional input information can be found in the input sheet forms located in Appendix A.) Card 1 is allocated to case identification. Card 2 shows that 40 cross-stream intervals are selected along with axisymmetric geometry, K-ϵ viscosity model, and

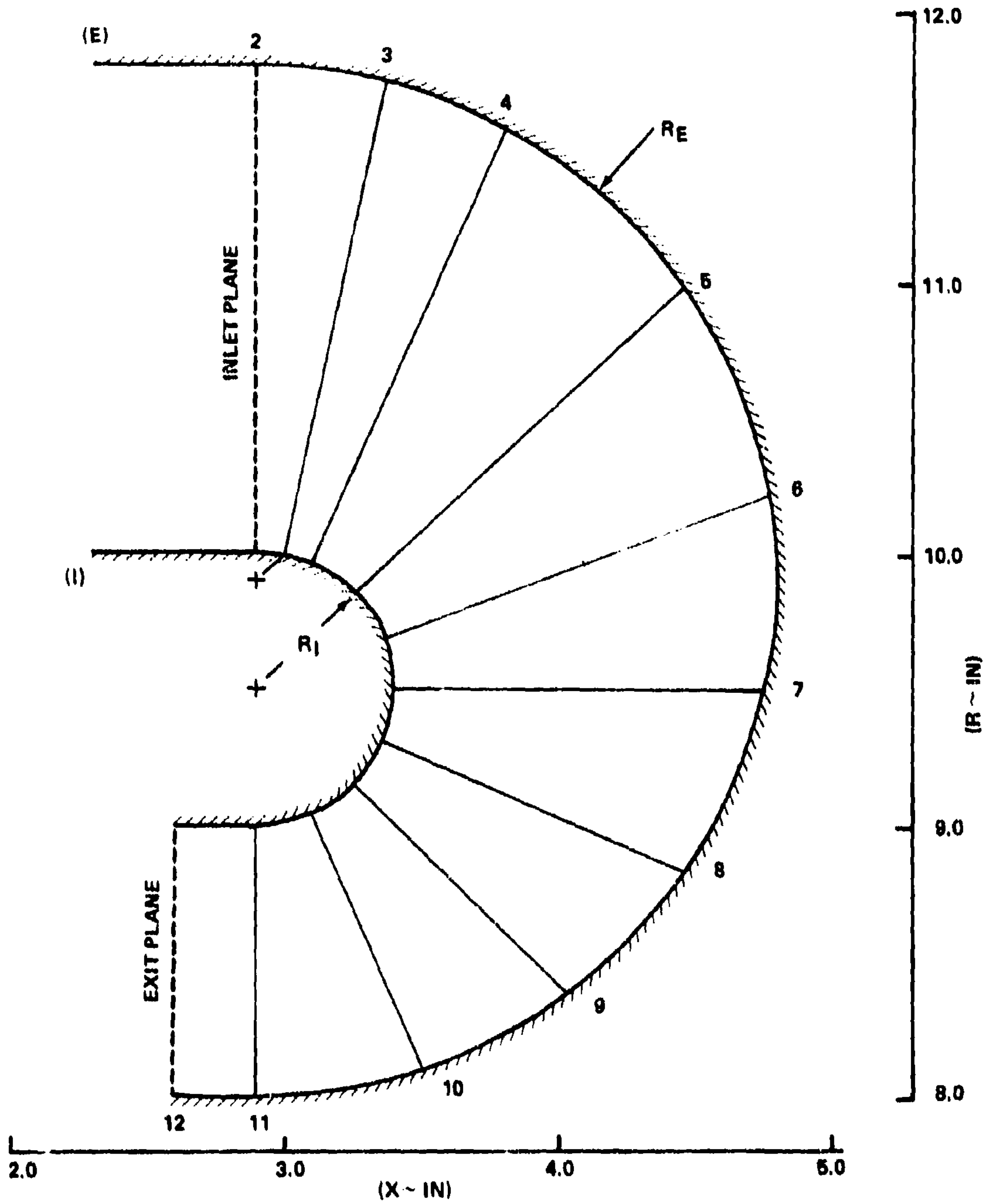


Figure 21. Transition Mixing Example Geometry.

CASE TITLE CARD (12A6)

Card								
1	TRANSI	TION M	IXING	MODEL	EXAMPL	E		

CASE TITLE CARD (12A6)

KPLANE	= 7						

(8(I2, 8X))

Card	N	KRAD	MASSTR	ISWRL	MODEL	INERT	IFLUX	ITEMP
2	40	01	00	00	02	01	00	01

(5(I5, 5X))

Card	NSTAT	NPROF	NPLOT	ITEST	LASTEP			
3	99999	00020	99999		99999			

(8E10.4)

Card	ZUI	ZUE	ZULAST	FRA	ZEND	ZOUT	PRESS	POWER
4	.07366	.07366	.2316	.02	10.	10.	101325	1.0

(8(I2, 8X))

Card	NBP	ICURV	NRCVI	NRCVE				
5	12	01	06	06				

(8E10.4)

Card	RI_1	XI_1	RI_2	XI_2	RI_3	XI_3	RI_4	$XI_4 \ldots$
6								

(8E10.4)

RE_1	XE_1	RE_2	XE_2	RE_3	XE_3	RE_4	$XE_4 \ldots$

(8E10.4)

Card	ZI_1	$RCVI_1$	ZI_2	$RCVI_2$	ZI_3	$RCVI_3$	ZI_4	$RCVI_4 \ldots$
7								

Figure 22. Transition Mixing Model Input Sheet (1 of 3)

(8E10.4)

	ZE_1	$RCVE_1$	ZE_2	$RCVE_2$	ZE_3	$RCVE_3$	ZE_4	$RCVE_4$...

(8E10.4)

	RA	RB	RD					
8	0.	.254	.29972					

NAMELIST

9	$INPUT	KREAD	= 1					$

(8E10.4)

	UA	UD						
10	0	0						

(8E10.4)

	F2A	F2D	TA	TD	T_{wall}			
11	0	0						

(I2)

	NIN							
12	19							

Y VALUES (8E10.4)

13								

U VALUES (8E10.4)

14								

15								

TEMPERATURE VALUES (8E10.4)

16								

Figure 22. Transition Mixing Model Input Sheet (2 of 3)

17								
18								
19								

TURBULENT KINETIC ENERGY (8E10.4)

20								

TURBULENCE LENGTH SCALE (8E10.4)

21								

Figure 22. Transition Mixing Model Input Sheet (3 of 3)

nonisothermal flow. Card 3 will allow a printout of the variable profiles at every 20 marching steps. The initial and final values of Z and the marching direction are placed on Card 4 along with the control on step size. Since the boundaries are always walls, ZOUT and ZEND are set to a large number while POWER equal to 1.0 forces the initial grid to be uniform in y. POWER >1.0 will distribute more nodes near the inner wall while 0 < POWER <1.0 will distort the grid toward the outer wall. Next, the number of boundary points and number of radius-of-curvature points are specified separated by a flag to indicate that radius-of-curvature effects are to be included. Card set 6 and 7 reads the actual boundary and curvature values which are listed in Table 2. The values listed are in inches and had to be converted to meters since the TMM requires S.I. units. The initial and final values of radius-of-curvature were just chosen to be a large (1000m) number. Cards 8 and 9 are quite obvious with the name-list variables listed with the input forms. Cards 10 and 11 deal with "free" boundaries, which are not used for this program, so the values listed are only for completeness. Card 12 indicates that 19 points on the input initial profile were used and correspond to the 19 radial nodes employed by the 3-D program. The various profiles are read on Cards 13 to 21 and are listed in Table 3. These profiles are merely the exit plane profiles for θ = 6 degrees (in line with the primary orifices) as obtained from the 3-D output.

The output of the TMMs is illustrated in Figure 23 (4 sheets). It begins with a list of control indices and important quantities followed by ω, the transformed cross-stream variable. The specified boundary values of X and R for the inner and outer wall along with the value of Z, the distance along the wall, are listed next. Following these are the values of radius-of-curvature and the initial profiles. Printing of the variable arrays starts with the value at the inner boundary and continues outward. Since y is always referenced from the inner boundary,

TABLE 2. TRANSITION MIXING MODEL GEOMETRY INPUT.

Point	XI	RI	XE	RE
1	0.0	10.0	0.0	11.8
2	2.9	10.0	2.9	11.8
3	3.01	9.99	3.37	11.73
4	3.10	9.96	3.80	11.56
5	3.26	9.85	4.45	10.98
6	3.37	9.68	4.76	10.20
7	3.40	9.50	4.75	9.50
8	3.37	9.30	4.45	8.79
9	3.26	9.14	4.02	8.38
10	3.10	9.04	3.51	8.10
11	2.90	9.00	2.90	8.00
12	2.60	9.00	2.60	8.00

Point	ZI	RCVI	ZE	RCVE
1	0.0	39370.0	0.0	39370.0
2	2.9	39370.0	2.9	39370.0
3	3.01	0.5	3.37	1.9
4	4.27	0.5	8.19	1.9
5	4.47	39370.0	8.81	39370.0
6	4.77	39370.0	9.11	39370.0

TABLE 3. INITIAL PROFILES (SI UNITS) FOR TRANSITION MIXING EXAMPLE

Node	r	u	KE	lm	Temp.
19	0.04572	32.6	15.6	5.86E-4	879
18	0.04318	32.6	15.6	5.86E-4	879
17	0.04064	22.8	18.0	6.03E-4	1310
16	0.03810	26.3	27.0	6.16E-4	1470
15	0.03556	29.2	30.3	6.50E-4	1530
14	0.03302	30.7	30.6	6.64E-4	1560
13	0.03048	31.7	29.6	6.65E-4	1570
12	0.02794	33.0	28.7	6.59E-4	1560
11	0.02540	34.6	29.9	6.42E-4	1530
10	0.02286	37.0	61.8	4.65E-4	1470
9	0.02032	34.5	42.9	6.24E-4	1550
8	0.01778	30.6	27.0	6.58E-4	1660
7	0.01524	28.7	26.4	6.57E-4	1700
6	0.01270	27.4	27.8	6.59E-4	1720
5	0.01016	25.9	28.3	6.49E-4	1690
4	0.00762	23.6	25.3	6.21E-4	1570
3	0.00508	21.6	20.4	6.10E-4	1370
2	0.00254	33.5	16.4	5.88E-4	879
1	0.00000	33.5	16.4	5.88E-4	879

K = 7

```
XYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXY
XYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXYXY

TRANSITION MIXING MODEL EXAMPLE
 KPLANE=7
MODER=  2 IORDER=  1 MODE=  2 MASSFR=  0 INERT=  1 KEAD=  1 IFLUX=  0
 UA        UD        TA          TD          RA          RR          ZEND        ZOUT        ZULAST      PRESS
 0.        0.        4.796E+02  5.793E+02  0.          2.540E-01  1.000E+01  1.000E+01  2.314E-01  1.013E+05
PREXPI    AEXPOI    CRI         PREXP2      AEXPO2      CR2         ETA         WID
5.000E+15 2.350E+04 5.000E+00  5.400E+08  1.250E+04  6.000E+00-0.             -0.

OMEGA      0.         0.         4.307E-02  9.032E-02  1.153E-01  1.403E-01  1.557E-01  1.757E-01  1.916E-01  2.080E-01  2.247E-01
           2.415E-01  2.583E-01  2.757E-01  2.956E-01  3.140E-01  3.337E-01  3.544E-01  3.771E-01  4.017E-01  4.280E-01  4.560E-01
           4.852E-01  5.111E-01  5.371E-01  5.423E-01  5.675E-01  6.112E-01  6.350E-01  6.586E-01  6.920E-01  7.052E-01  7.281E-01
           7.537E-01  7.777E-01  7.944E-01  8.159E-01  8.306E-01  8.584E-01  9.085E-01  9.542E-01  1.000E+00  1.000E+00

            INTERNAL BOUNDARY                              EXTERNAL BOUNDARY

  I        X           R           Z            I        X           R           Z
  1   0.           .2540E+00  0.               1   0.           .2997E+00  0.
  2    .7365E-01   .2540E+00   .7365E-01       2    .7366E-01   .2997E+00   .7366E-01
  3    .7645E-01   .2537E+00   .7647E-01       3    .9566E-01   .2979E+00   .8573E-01
  4    .7374E-01   .2530E+00   .7886E-01       4    .9652E-01   .2936E+00   .9749E-01
  5    .9280E-01   .2532E+00   .8379E-01       5    .1130E+00   .2786E+00   .1196E+00
  6    .9560E-01   .2459E+00   .8897E-01       6    .1209E+00   .2551E+00   .1409E+00
  7    .9634E-01   .2413E+00   .9359E-01       7    .1256E+00   .2413E+00   .1587E+00
  8    .9550E-01   .2362E+00   .9974E-01       8    .1130E+00   .2233E+00   .1793E+00
  9    .9250E-01   .2322E+00   .1036E+00       9    .1071E+00   .2129E+00   .1934E+00
 10    .7874E-01   .2296E+00   .1064E+00      10    .8915E-01   .2057E+00   .2081E+00
 11    .7365E-01   .2285E+00   .1136E+00      11    .7366E-01   .2037E+00   .2239E+00
 12    .4000E-01   .2256E+00   .1473E+00      12    .4000E-01   .2032E+00   .2575E+00

            INTERNAL BOUNDARY                              EXTERNAL BOUNDARY

  I        Z                       RCVI         I        Z                       RCVE
  1   0.                          .1000E+04     1   0.                          .1000E+04
  2    .7365E-01                  .1000E+04     2    .7366E-01                  .1000E+04
  3    .7647E-01                  .1270E-01     3    .8573E-01                  .4826E-01
  4    .1034E+00                  .1270E-01     4    .2081E+00                  .4826E-01
  5    .1136E+00                  .1000E+04     5    .2238E+00                  .1000E+04
  6    .1212E+00                  .1000E+04     6    .2315E+00                  .1000E+04

ISTEP=     0 IA4=10000 IEND=10000 IOUT=10000 KIN= 1 KEX= 1 DZI=  2.125E-05 DZE=  9.143E-05 PSII=  0.        PSIE=  9.726E-02
RMI=  0.          RME=  0.          PEI=  9.726E-02 PRESSD=  0.              AFXD=  0.
XI=  7.367E-02 XE=  7.367E-02 EI=  2.540E-01 EE=  2.997E-01 RCVI=  9.954E+02 RCVE=  9.991E+02 CSALFA=  1.000E+00
ZUI=  7.367E-02 ZUE=  7.367E-02 UFLUX= 2.967E+00 FLUX(J)= 5.976E+04 0.        0.        0.        0.          2.639E+00 2.179E+03
KIN= 1 TAUID=  1.678E-02 AJID(J)=  0.        0.        0.        0.        0.        0.          -5.867E-03
KEX= 1 TAUED=  1.454E-02 AJED(J)=  0.        0.        0.        0.        0.        0.           5.450E-03

RI,Y'S     2.540E-01  5.930E-16  1.143E-03  2.286E-03  3.429E-03  4.571E-03  5.714E-03  6.857E-03  8.000E-03  9.143E-03  1.029E-02
           1.143E-02  1.257E-02  1.371E-02  1.486E-02  1.600E-02  1.714E-02  1.829E-02  1.943E-02  2.057E-02  2.171E-02  2.286E-02
           2.400E-02  2.514E-02  2.629E-02  2.743E-02  2.857E-02  2.971E-02  3.086E-02  3.200E-02  3.314E-02  3.429E-02  3.543E-02
           3.657E-02  3.771E-02  3.886E-02  4.000E-02  4.114E-02  4.229E-02  4.343E-02  4.457E-02  4.571E-02  4.571E-02

U          0.         3.350E+01  3.350E+01  3.350E+01  2.934E+01  2.399E+01  2.210E+01  2.300E+01  2.394E+01  2.498E+01  2.597E+01
           2.655E+01  2.732E+01  2.792E+01  2.850E+01  2.927E+01  3.012E+01  3.139E+01  3.313E+01  3.475E+01  3.587E+01  3.700E+01
           3.592E+01  3.484E+01  3.434E+01  3.332E+01  3.266E+01  3.209E+01  3.155E+01  3.110E+01  3.063E+01  2.995E+01  2.929E+01
           2.604E+01  2.674E+01  2.525E+01  2.368E+01  2.476E+01  2.917E+01  3.260E+01  3.260E+01  3.260E+01  0.

KE         0.         1.640E+01  1.640E+01  1.640E+01  1.786E+01  1.950E+01  2.162E+01  2.383E+01  2.575E+01  2.710E+01  2.828E+01
           2.635E+01  2.783E+01  2.724E+01  2.561E+01  2.658E+01  2.685E+01  3.018E+01  3.733E+01  4.479E+01  5.329E+01  6.190E+01
           4.745E+01  3.309E+01  2.968E+01  2.594E+01  2.892E+01  2.933E+01  2.975E+01  3.020E+01  3.059E+01  3.045E+01  3.032E+01
           2.435E+01  2.753E+01  2.430E+01  2.025E+01  1.752E+01  1.644E+01  1.560E+01  1.550E+01  1.560E+01  0.
```

Figure 23. Transition Mixing Model Output (Sheet 1 of 4).

```
LEN SC    0.          5.8??E-04   [illegible] [illegible] 5.957E-04   6.556E-04   6.127E-04   6.177E-04   6.252E-04   6.278E-04   6.495E-04
          [illegible] [illegible] [illegible] [illegible] [illegible] 6.577E-04   6.512E-04   6.359E-04   6.091E-04   5.966E-04   [illegible]
          [illegible] [illegible] [illegible] [illegible] [illegible] 6.632E-04   5.669E-04   5.644E-04   6.611E-04   5.572E-04   6.557E-04
          [illegible] [illegible] [illegible] [illegible] 5.944E-04   5.920E-04   5.860E-04   5.860E-04   5.860E-04   0.
TEMP      [illegible] [illegible] [illegible] [illegible] 1.49?E+03   1.277E+03   1.423E+03   1.510E+03   1.548E+03   1.642E+03   1.691E+03
          [illegible] [illegible] [illegible] [illegible] [illegible] 1.672E+03   1.433E+03   1.589E+03   1.542E+03   1.504E+03   1.475E+03
          [illegible] [illegible] [illegible] 1.564E+03   [illegible] 1.567E+03   1.529E+03   1.564E+03   1.559E+03   1.545E+03   1.532E+03
          [illegible] [illegible] [illegible] [illegible] 1.224E+03   1.233E+03   9.795E+02   9.795E+02   9.795E+02   9.795E+02
PRESS     [illegible] [illegible] [illegible] [illegible] [illegible] -8.277E-03  [illegible] -8.556E-03  -8.415E-03  -8.276E-03  -8.117E-03
          [illegible] [illegible] [illegible] [illegible] -7.237E-03  -7.573E-03  [illegible] -6.579E-03  -6.294E-03  -5.579E-03  -5.631E-03
          [illegible] [illegible] [illegible] [illegible] [illegible] -3.727E-03  [illegible] -3.227E-03  -2.958E-03  -2.716E-03  -2.493E-03
          [illegible] [illegible] [illegible] [illegible] [illegible] -1.354E-03  -4.793E-04  -6.861E-04  0.          1.013E-03
AMULT     [illegible] [illegible] [illegible] [illegible] [illegible] 6.751E-04   [illegible] 6.374E-04   6.267E-04   6.293E-04   6.326E-04
          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 2.237E-02   2.528E-02   2.614E-02
          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 3.374E-02   3.502E-02   3.516E-02
U         0.          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 6.114E+01   6.531E+01   6.051E+01   5.993E+01
          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 6.283E+01   5.729E+01   5.152E+01   4.945E+01
          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 5.565E+01   3.817E+01   3.688E+01   3.551E+01
          [illegible] [illegible] [illegible] [illegible] 3.179E+01   [illegible] 3.199E+01   2.913E+01   1.957E+01   0.
KE        0.          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 1.756E+01   1.816E+01   [illegible]
          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 2.106E+01   2.197E+01   2.244E+01   2.224E+01
          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 1.662E+01   1.661E+01   1.390E+01   1.31?E+01
          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 1.026E+01   5.939E+00   0.
LEN SC    0.          5.7??E-04   [illegible] [illegible] [illegible] [illegible] 7.049E-04   7.176E-04   7.285E-04   7.410E-04   7.545E-04
          7.???E-04   [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 7.725E-04   7.551E-04   7.325E-04   7.2??E-04
          7.55?E-04   7.912E-04   [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 9.725E-04   9.860E-04   9.8??E-04
          [illegible] [illegible] 9.738E-04   [illegible] [illegible] 6.622E-04   7.353E-04   5.45?E-04   1.032E-04   0.
TEMP      [illegible] [illegible] [illegible] 1.092E+03   1.287E+03   1.353E+03   1.464E+03   1.531E+03   1.546E+03   1.633E+03   1.654E+03
          [illegible] [illegible] [illegible] 1.476E+03   1.654E+03   1.690E+03   1.603E+03   1.573E+03   1.562E+03   1.523E+03   [illegible]
          [illegible] [illegible] [illegible] [illegible] [illegible] 1.557E+03   1.555E+03   1.549E+03   1.536E+03   1.513E+03   1.4??E+03
          [illegible] [illegible] [illegible] [illegible] 1.144E+03   1.265E+03   9.827E+02   9.255E+02   8.934E+02   9.379E+02
PRESS     -1.037E+03  -5.4??E+02  -5.917E+02  -5.126E+02  -4.557E+02  -4.193E+02  -3.945E+02  -3.734E+02  -3.539E+02  -3.351E+02  -3.171E+02
          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] -2.075E+02  -1.927E+02  -1.771E+02  -1.623E+02  -1.47?E+02
          [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] -7.294E+01  -6.579E+01  -5.416E+01  -4.304E+01  -4.7??E+01
          [illegible] -3.779E+01  -3.337E+01  [illegible] -2.354E+01  -2.376E+01  -1.4??E+01  -7.029E+00  0.          1.513E+05
AMULT     [illegible] 5.27?E-04   [illegible] [illegible] [illegible] 6.29?E-04   6.151E-04   6.063E-04   6.028E-04   6.043E-04   6.09?E-04
          [illegible] [illegible] [illegible] [illegible] [illegible] 4.703E-04   4.844E-04   4.979E-04   5.064E-04   5.054E-04   5.039E-04
          [illegible] [illegible] [illegible] [illegible] 5.370E-04   5.386E-04   5.377E-04   5.416E-04   5.465E-04   5.602E-04   5.493E-04
          [illegible] [illegible] [illegible] [illegible] 5.535E-04   5.492E-04   4.932E-04   4.527E-04   8.301E-05   4.035E-05
ISTEP= [illegible] TAV=[illegible] TEND=[illegible] [illegible] KEN= 1 KES= 1 DZI= 1.708E-04 DZE= 6.084E-04 PSII= 0.   PSIE= 9.774E-02
RHO= 0.   [illegible]= 0.   [illegible]= 5.726E-02 PRESSO= -2.672E-04 REFTD= -2.588E-05
R1= [illegible] R2= 1.266E-01 [illegible] [illegible] [illegible]= 2.365E-01 [illegible]= 1.276E-02 [illegible]= 6.627E-02 CTALFA= -1.964E-01
ZUI= [illegible] ZUE= [illegible] UFLUX= 5.037E+03 FLUX(I)= 5.143E+04 0.   0.   0.   0.   1.474E+05 7.990E+07
ETA= [illegible] [illegible] [illegible] [illegible]  0.   0.   0.   0.   0.   0.   -3.042E-03
KEN= 1 [illegible] 3.242E-03 AJEC(I)= 0.  0.  0.  0.  0.  0.  2.956E-03
BLAST     [illegible] [illegible] 7.233E-04   1.445E-03   2.184E-03   2.730E-03   3.177E-03   3.597E-03   4.029E-03   4.479E-03   4.951E-03
          [illegible] [illegible] [illegible] 7.244E-03   7.626E-03   [illegible] 8.433E-03   9.585E-03   1.034E-02   1.116E-02   1.204E-02
          [illegible] [illegible] 1.475E-02   1.564E-02   1.635E-02   1.765E-02   1.838E-02   1.931E-02   2.026E-02   2.121E-02   2.216E-02
          [illegible] 2.402E-02   2.446E-02   2.574E-02   2.652E-02   2.769E-02   2.956E-02   3.061E-02   3.232E-02   3.242E-02
U         0.          [illegible] [illegible] 6.655E+01   6.795E+01   6.822E+01   6.433E+01   6.826E+01   6.806E+01   6.771E+01   6.712E+01
          [illegible] [illegible] [illegible] 6.326E+01   6.216E+01   6.159E+01   5.953E+01   5.897E+01   5.794E+01   5.665E+01   5.531E+01
          [illegible] [illegible] 5.119E+01   4.995E+01   4.864E+01   4.749E+01   4.617E+01   4.491E+01   4.362E+01   4.226E+01   4.091E+01
          [illegible] 3.838E+01   3.739E+01   3.665E+01   3.607E+01   3.544E+01   3.441E+01   3.157E+01   2.149E+01   0.
KE        0.          [illegible] 1.457E+01   1.716E+01   1.579E+01   1.569E+01   1.596E+01   1.639E+01   1.694E+01   1.751E+01   1.8??E+01
          [illegible] [illegible] [illegible] 1.647E+01   1.654E+01   1.865E+01   1.945E+01   2.010E+01   2.074E+01   2.109E+01   2.093E+01
          [illegible] [illegible] 1.214E+01   1.712E+01   1.826E+01   1.548E+01   1.492E+01   1.447E+01   1.405E+01   1.353E+01   1.274E+01
          [illegible] [illegible] 9.453E+00   9.592E+00   8.043E+00   7.711E+00   8.395E+00   1.144E+01   5.642E+00   0.
```

Figure 23. Transition Mixing Model Output (Sheet 2 of 4).

```
LEN SC    0.         6.256E-05  3.450E-04  5.533E-04  6.420E-04  6.912E-04  7.133E-04  7.270E-04  7.386E-04  7.511E-04  7.656E-04
          7.837E-04  7.959E-04  8.099E-04  8.210E-04  8.264E-04  8.230E-04  8.104E-04  7.919E-04  7.725E-04  7.589E-04  7.599E-04
          7.793E-04  8.175E-04  8.526E-04  9.052E-04  9.396E-04  9.658E-04  9.959E-04  1.002E-03  1.014E-03  1.021E-03  1.024E-03
          1.022E-03  1.018E-03  1.008E-03  9.894E-04  9.541E-04  8.539E-04  7.324E-04  5.700E-04  1.634E-04  0.

TEMP      9.451E+02  9.686E+02  1.025E+03  1.123E+03  1.283E+03  1.386E+03  1.463E+03  1.526E+03  1.581E+03  1.625E+03  1.657E+03
          1.675E+03  1.685E+03  1.691E+03  1.669E+03  1.650E+03  1.626E+03  1.598E+03  1.570E+03  1.544E+03  1.526E+03  1.519E+03
          1.522E+03  1.530E+03  1.540E+03  1.546E+03  1.553E+03  1.554E+03  1.551E+03  1.543E+03  1.527E+03  1.503E+03  1.465E+03
          1.415E+03  1.353E+03  1.285E+03  1.216E+03  1.146E+03  1.062E+03  9.865E+02  9.239E+02  8.936E+02  9.114E+02

PRESS     1.036E+05 -7.446E+02 -6.949E+02 -5.981E+02 -5.350E+02 -4.940E+02 -4.653E+02 -4.415E+02 -4.192E+02 -3.976E+02 -3.767E+02
         -3.557E+02 -3.373E+02 -3.166E+02 -3.005E+02 -2.828E+02 -2.656E+02 -2.494E+02 -2.316E+02 -2.132E+02 -1.952E+02 -1.774E+02
         -1.606E+02 -1.456E+02 -1.322E+02 -1.201E+02 -1.090E+02 -9.862E+01 -8.945E+01 -8.078E+01 -7.272E+01 -6.525E+01 -5.836E+01
         -5.235E+01 -4.631E+01 -4.106E+01 -3.617E+01 -3.117E+01 -2.561E+01 -1.706E+01 -8.285E+00  0.         1.013E+05

AMU(I)    4.124E-05  5.216E-05  2.962E-04  4.544E-04  4.322E-04  4.233E-04  4.135E-04  4.057E-04  4.021E-04  4.038E-04  4.100E-04
          4.193E-04  4.290E-04  4.397E-04  4.515E-04  4.642E-04  4.769E-04  4.934E-04  4.977E-04  5.037E-04  5.059E-04  5.073E-04
          5.131E-04  5.237E-04  5.355E-04  5.444E-04  5.492E-04  5.519E-04  5.552E-04  5.602E-04  5.663E-04  5.708E-04  5.714E-04
          5.674E-04  5.611E-04  5.559E-04  5.535E-04  5.514E-04  5.376E-04  4.883E-04  4.829E-04  7.840E-05  4.043E-05

ISTEP=  180 IAX=10000 IEND=10000 IOUT=10000 KIN= 1 KEX= 1 DZI=  1.604E-04 DZE=  5.090E-04 PSII=  0.         PSIE=  9.726E-02
RMI=  0.         RME=  0.         PEI=  9.726E-02 PRESSD= -6.711E-04 AEXD=  1.152E-04
XI=  9.567E-02 XE=  1.137E-01 RI=  2.367E-01 RE=  2.250E-01 RCVI=  1.281E-02 RCVE=  4.603E-02 CSALFA= -3.852E-01
ZUI=  9.826E-02 ZUE=  1.764E-01 UFLUX= 5.566E+00 FLUX(J)= 6.161E+04 0.         0.         0.         0.         1.462E+00 8.309E+02
KIN= 1 TAUID=  1.745E-02 AJID(J)=  0.         0.         0.         0.         0.         0.        -3.767E-02
KEX= 1 TAUED=  3.138E-03 AJED(J)=  0.         0.         0.         0.         0.         0.         3.807E-03

RI,Y'S    2.367E-01  9.474E-05  7.535E-04  1.427E-03  2.116E-03  2.646E-03  3.060E-03  3.449E-03  3.847E-03  4.261E-03  4.694E-03
          5.145E-03  5.617E-03  6.104E-03  6.621E-03  7.158E-03  7.721E-03  8.317E-03  8.964E-03  9.672E-03  1.044E-02  1.126E-02
          1.212E-02  1.295E-02  1.379E-02  1.462E-02  1.546E-02  1.630E-02  1.715E-02  1.801E-02  1.889E-02  1.976E-02  2.063E-02
          2.149E-02  2.233E-02  2.313E-02  2.391E-02  2.472E-02  2.573E-02  2.704E-02  2.854E-02  3.021E-02  3.045E-02

ISTEP=  245 IAX=10000 IEND=10000 IOUT=10000 KIN= 1 KEX= 1 DZI=  2.4[illegible]E-04 DZE=  2.4[illegible]E-04 PSII=  0.         PSIE= [illegible]
RMI=  0.         RME=  0.         PEI=  9.726E-02 PRESSD= -4.997E-03 AEXD=  2.595E-04
XI=  6.609E-02 XE=  6.609E-02 RI=  2.286E-01 RE=  2.032E-01 RCVI=  1.000E+03 RCVE=  1.000E+03 CSALFA= -1.000E+00
ZUI=  1.212E-01 ZUE=  2.316E-01 UFLUX= 6.849E+00 FLUX(J)= 6.222E+04 0.         0.         0.         0.         1.766E+00 1.493E+03
KIN= 1 TAUID=  6.234E-03 AJID(J)=  0.         0.         0.         0.         0.         0.        -4.132E-02
KEX= 1 TAUED=  5.042E-03 AJED(J)=  0.         0.         0.         0.         0.         0.         1.857E-02

RI,Y'S    2.286E-01  1.152E-04  9.755E-04  1.855E-03  2.719E-03  3.336E-03  3.930E-03  4.225E-03  4.652E-03  5.096E-03  5.530E-03
          5.987E-03  6.456E-03  6.938E-03  7.435E-03  7.947E-03  8.479E-03  9.037E-03  9.636E-03  1.028E-02  1.098E-02  1.171E-02
          1.245E-02  1.315E-02  1.384E-02  1.451E-02  1.516E-02  1.581E-02  1.644E-02  1.707E-02  1.768E-02  1.829E-02  1.888E-02
          1.945E-02  2.000E-02  2.053E-02  2.104E-02  2.158E-02  2.226E-02  2.316E-02  2.417E-02  2.527E-02  2.541E-02

U         0.         4.380E+01  6.641E+01  6.409E+01  6.933E+01  7.097E+01  7.185E+01  7.269E+01  7.349E+01  7.421E+01  7.480E+01
          7.525E+01  7.555E+01  7.573E+01  7.580E+01  7.591E+01  7.575E+01  7.566E+01  7.554E+01  7.542E+01  7.531E+01  7.535E+01
          7.524E+01  7.526E+01  7.527E+01  7.526E+01  7.516E+01  7.493E+01  7.470E+01  7.429E+01  7.372E+01  7.302E+01  7.219E+01
          7.126E+01  7.028E+01  6.976E+01  6.420E+01  6.795E+01  6.531E+01  6.272E+01  5.852E+01  4.426E+01  0.

KE        0.         4.395E+01  2.455E+01  1.755E+01  1.763E+01  1.560E+01  1.524E+01  1.535E+01  1.552E+01  1.577E+01  1.611E+01
          1.656E+01  1.701E+01  1.747E+01  1.756E+01  1.815E+01  1.833E+01  1.841E+01  1.837E+01  1.822E+01  1.795E+01  1.755E+01
          1.737E+01  1.557E+01  1.539E+01  1.555E+01  1.536E+01  1.515E+01  1.505E+01  1.534E+01  1.517E+01  1.528E+01  1.538E+01
          1.544E+01  1.549E+01  1.559E+01  1.590E+01  1.624E+01  1.730E+01  2.047E+01  2.977E+01  1.182E+01  0.

LEN SC    0.         1.580E-04  1.772E-04  3.347E-04  4.747E-04  5.932E-04  6.730E-04  7.283E-04  7.623E-04  7.857E-04  8.055E-04
          8.279E-04  8.491E-04  8.980E-04  9.826E-04  8.922E-04  8.959E-04  8.944E-04  8.892E-04  8.932E-04  8.909E-04  8.974E-04
          9.055E-04  9.335E-04  9.531E-04  1.006E-03  1.042E-03  1.074E-03  1.100E-03  1.119E-03  1.133E-03  1.143E-03  1.150E-03
          1.153E-03  1.146E-03  1.120E-03  1.066E-03  9.763E-04  8.243E-04  6.132E-04  4.554E-04  1.013E-04  0.

TEMP      1.036E+03  1.064E+03  1.101E+03  1.265E+03  1.371E+03  1.436E+03  1.479E+03  1.515E+03  1.556E+03  1.585E+03  1.611E+03
          1.624E+03  1.637E+03  1.639E+03  1.634E+03  1.623E+03  1.609E+03  1.592E+03  1.574E+03  1.558E+03  1.544E+03  1.537E+03
          1.534E+03  1.535E+03  1.537E+03  1.537E+03  1.534E+03  1.527E+03  1.514E+03  1.493E+03  1.455E+03  1.431E+03  1.390E+03
          1.346E+03  1.300E+03  1.254E+03  1.208E+03  1.160E+03  1.099E+03  1.025E+03  9.645E+02  9.221E+02  9.443E+02

PRESS     1.038E+05 -3.173E-02 -3.134E-02 -2.979E-02 -2.833E-02 -2.808E-02 -2.751E-02 -2.709E-02 -2.648E-02 -2.595E-02 -2.541E-02
         -2.435E-02 -2.428E-02 -2.370E-02 -2.309E-02 -2.266E-02 -2.180E-02 -2.110E-02 -2.035E-02 -1.953E-02 -1.865E-02 -1.771E-02
         -1.675E-02 -1.584E-02 -1.498E-02 -1.409E-02 -1.325E-02 -1.242E-02 -1.160E-02 -1.090E-02 -1.000E-02 -9.220E-03 -8.450E-03
         -7.730E-03 -5.976E-03 -5.774E-03 -5.585E-03 -4.861E-03 -3.940E-03 -2.721E-03 -1.357E-03  0.         1.008E+05

AMU(I)    4.439E-05  1.212E-04  1.427E-04  2.672E-04  2.866E-04  3.234E-04  3.672E-04  3.929E-04  4.056E-04  4.130E-04  4.243E-04
          4.335E-04  4.588E-04  4.777E-04  4.996E-04  5.165E-04  5.296E-04  5.376E-04  5.415E-04  5.422E-04  5.417E-04  5.429E-04
          5.495E-04  5.590E-04  5.740E-04  5.926E-04  6.137E-04  6.369E-04  6.622E-04  6.903E-04  7.225E-04  7.593E-04  7.499E-04
          8.414E-04  8.774E-04  9.333E-04  8.982E-04  8.660E-04  7.852E-04  5.629E-04  5.277E-04  7.054E-05  4.115E-05
```

Figure 23. Transition Mixing Model Output (Sheet 3 of 4).

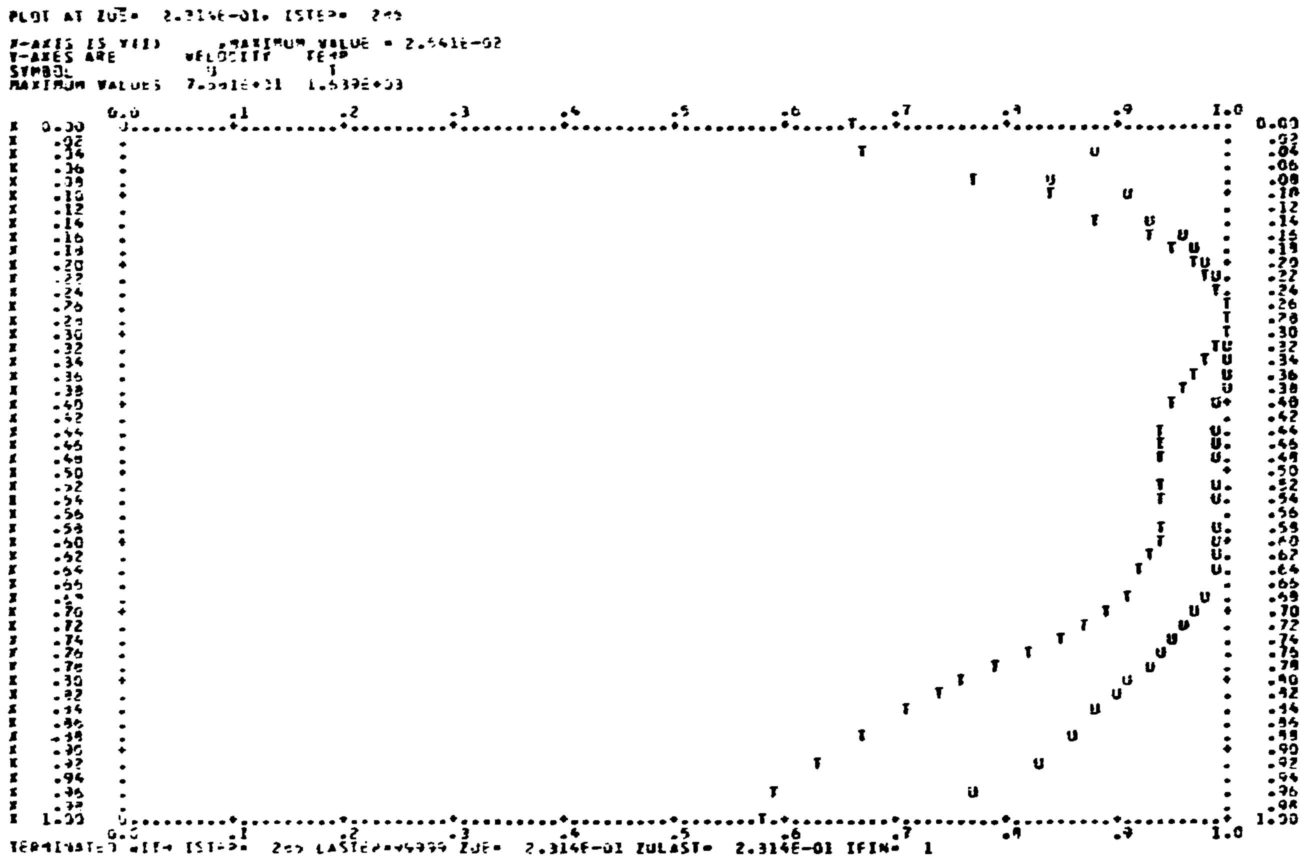


Figure 23. Transition Mixing Model Output (Sheet 4 of 4).

Y(1) is always zero; therefore, the radius of the inner boundary is printed instead. Note that the pressure variation across the grid (PRESS) is essentially zero due to the large values of radius-of-curvature (RCVI, RCVE) specified at the inlet plane. Sheets 2 and 3 of Figure 23 show the printout after 160 marching steps. Along the outer boundary, the program has marched to 0.1639 meter (ZUE), but the inner boundary is only to 0.09497 meter (ZUI). At this point, there exists a considerable radial pressure gradient with the inner wall at 744 N/m^2 lower pressure than the outer. In addition, the velocity profile is distorted so that the maximum is very near the inner wall. Sheets 3 and 4 of Figure 23 show the output at the exit plane. The radial-pressure gradient disappears as the radius-of-curvature effects are no longer present. A plot of velocity and temperature is also made. The top line of the plot corresponds to the inner boundary while the bottom line is the outer. However, it must be remembered that the inner boundary here is located at what would be the stator-blade tip and the outer at what would be the blade root.

EMISSION MODEL

The calculation domain that would be used by the emission model to predict the emission output of the example combustor is illustrated in Figure 24. Starting with the initial profiles near the dome, the program marches using the recirculation zone as the inner boundary. The mass and specie concentrations in the recirculation zone can be estimated or calculated by several methods, and this provides an entrainment rate and boundary conditions. Once the centerline of the combustor is reached, the inner boundary switches to an axis of symmetry. Cooling slots and radial-injection points can be handled without stopping the marching process. To input the information necessary to perform the above calculation would be quite lengthy and illustrates nothing about the emission program. Usually, the boundary along

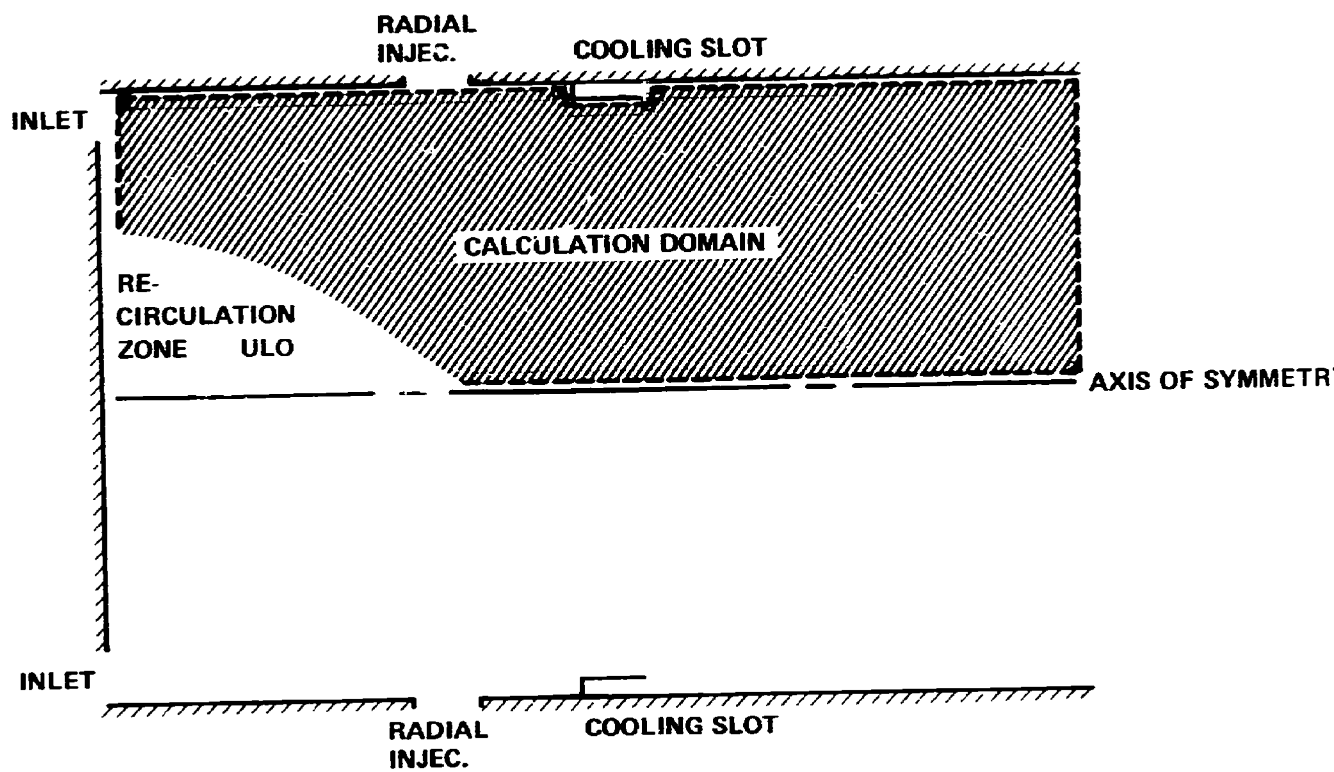


Figure 24. Calculation Domain for Predicting Emission Output of Example Combustor.

the recirculation zone must be handled in a manner that requires internal modifications to the program similar to the Cards MA.528 through MA.743 that are unique to each case analyzed. Therefore, for the example case (Figure 25) the program is started at the downstream edge of the cooling-slot lip and marched to the exit of the liner.

As illustrated in Figure 25, card set 1 is available for case identification. Card 2 specifies 30 cross-stream intervals, axisymmetric geometry, species, two-equation turbulence model, reaction and nonisothermal conditions, while Card 3 produces a profile printout at every 40 marching steps. The initial and final x locations are read on Card 4 and have units of meters, since all the units of the emission model are S.I. The step size was chosen to be small as is necessary with the 16-step kinetic scheme. Since the boundaries are always walls, XOUT AND XEND are set to a large number. A value of POWER equal to 1.0 provides an initial grid that is uniform in y. POWER >1.0 places more nodes near the inner boundary while POWER <-1.0 places more nodes near the outer boundary. Since both walls are straight, only two boundary points are needed, Cards 5 and 6. Cards 7 and 8 define the initial grid, inner and outer radii, and the name-list quantities. Cards 9 and 10 deal with quantities at free boundaries, which are not used, so the data is included only for completeness. The initial profiles are the same as those used in the wall-cooling model example. Nineteen points are used and correspond to the 19 radial nodes used in the 3-D performance model. Three additional profiles, listed in Table 4, are needed for the 16-step-reaction scheme. Since for this case there are no cooling slots or radial injections, the remaining Cards, 24 through 51, are omitted.

CASE TITLE CARD (12A6)

1	EMISSI	ON MOD	EL EXA	MPLE				

CASE TITLE CARD (12A6)

KPLANE	=7						

(8(I2, 8X))

	N	KRAD	MASSTR	ISWRL	MODEL	INERT	IFLUX	ITEMP
2	30	01	01	00	02	02	00	01

(5(I5, 5X))

	NSTAT	NPROF	NPLOT	ITEST	LASTEP			
3	99999	00040	99999		99999			

(8E10.4)

	XU	XULAST	FRA	XEND	XOUT	PRESS	POWER	
4	.03937	.073	.01	10.	10.	101325	1.0	

(I2)

	NBP							
5	02							

	X_1	RI_1	RE_1	X_2	RI_2	RE_2	X_3	RI_3
6	0	.254	.29972	10.	.254	.29972		

(8E10.4)

RE_3	X_4	RI_4	RE_4	X_5	RI_5	RE ...	

(8E10.4)

	RA	RB	RD					
7	0	.254	.29972					

Figure 25. Emissions Model Input Sheet (1 of 4)

NAMELIST

8 $INPUT KREAD=1, PREXD1 = 2.8E+16, ARGON1 = 54000. $
CR1=3.0, CX=10, MY=19.28, ERO=1.5, EFU=.5, EO2=1.0
EH2O=0.

	UA	UD	VTA	VTD				(8E10.4)
9	0	0	0	0				

	F2A	F2D	TA	TD	T_{wall}			(8E10.4)
10	0	0	589.	589.	589.			

	NIN	NUI	NUE	NVI	NVE			(5(I2, 8X))
11	19	00	00	00	00			

Y VALUES (8E10.4)

12								

U VALUES (8E10.4)

13								

Vθ VALUES (8E10.4)

14								

TEMPERATURE VALUES (8E10.4)

15								

MFU VALUES (8E10.4)

16								

MCO_2 VALUES (8E10.4)

17								

Figure 25. Emissions Model Input Sheet (2 of 4)

MCO VALUES (8E10.4)

18								

MOX VALUES (8E10.4)

19								

MH_2O VALUES (8E10.4)

20								

MH_2 VALUES (8E10.4)

21								

TURBULENT KINETIC ENERGY (8E10.4)

22								

TURBULENCE LENGTH SCALE (8E10.4)

23								

SKIP FOLLOWING CARD SET IF NUI = 0

X - LOC. OF INTERNAL COOLING SLOTS (8E10.4)

24								

LIP LENGTH OF INTERNAL COOLING SLOTS (8E10.4)

25								

U - VELOCITY OF INTERNAL COOLING SLOTS (8E10.4)

26								

VT - VELOCITY OF INTERNAL COOLING SLOTS (8E10.4)

27								

Figure 25. Emissions Model Input Sheet (3 of 4)

TEMPERATURE OF INTERNAL COOLING SLOTS (8E10.4)

FLOW RATE OF INTERNAL COOLING SLOTS (8E10.4)

29

SLOT HEIGHT OF INTERNAL COOLING SLOTS (8E10.4)

30

SLOT TO METERING AREA RATIO FOR INT SLOTS (8E10.4)

31

SKIP FOLLOWING CARD SET IF NUE = 0

X-LOC OF EXTERNAL COOLING SLOTS (8E10.4)

32

LIP LENGTH OF EXTERNAL COOLING SLOTS (8E10.4)

33

U - VELOCITY OF EXTERNAL COOLING SLOTS (8E10.4)

34

V_T - VELOCITY OF EXTERNAL COOLING SLOTS (8E10.4)

35

Figure 25. Emissions Model Input Sheet (4 of 4)

TABLE 4. ADDITIONAL PROFILES FOR EMISSION MODEL.

Node	M_{CO_2}	M_{OX}	M_{H_2O}
19	0	0.232	0
18	0	0.232	0
17	0.0318	0.170	0.0243
16	0.0368	0.163	0.0272
15	0.0311	0.157	0.0291
14	0.0484	0.153	0.0304
13	0.0534	0.151	0.0309
12	0.0494	0.157	0.0282
11	0.0274	0.188	0.0169
10	0.0199	0.200	0.0123
9	0.0527	0.156	0.0282
8	0.0657	0.140	0.0339
7	0.0596	0.142	0.0338
6	0.0537	0.146	0.0333
5	0.0486	0.149	0.0325
4	0.0438	0.152	0.0314
3	0.0400	0.158	0.0293
2	0	0.232	0
1	0	0.232	0

The output of the emission model is shown in Figures 26 and 27. The initial printout consists of some control parameters, the value omega (the transformed cross-stream variable), and the initial profiles. The printing of the variable arrays starts with the value at the inner boundary and continues outward. Since y is always referenced from the inner boundary, y(1) is always zero; therefore, the radius of the inner boundary is printed instead. Figure 27 shows the profiles at the exit of the combustor, XU = 0.073 meter. The profiles of NO show small values (much less, however, than one would expect as the principal area of NO formation) occur upstream of where the emission model is started.

FUEL-INSERTION MODEL

The fuel-insertion model could have been used to predict the droplet trajectories of the nozzle in the 3-D performance model example case, Figure 28; however, since that program contains its own spray model, a simple illustrative example was selected instead. A two-dimensional grid 5.0 X 1.5 inches, with the spray originating in the lower left-hand corner and processing a nonuniform flow field, was analyzed.

Card 1 (Figure 28, Sheet 1) allows for case identification. Card 2 specifies the atomizer type, in this case an airblast nozzle with a 10 flow no. and 90-degree cone angle. The other fields are left blank as they pertain to dual orifice and/or simplex nozzles. Cards 3 and 4 are omitted as they are used to input the ΔP versus fuel-flow curve for the secondaries of a dual-orifice nozzle. Card 5 specifies some dimensions of the airblast nozzle, the filming diameter, and exit-flow area along with the airflow rate and temperature. The fuel type, flow rate, and temperature are given on Card 6, plus the flag to specify a nonuniform 2-D field. Other quantities on Card 6 are required only for other

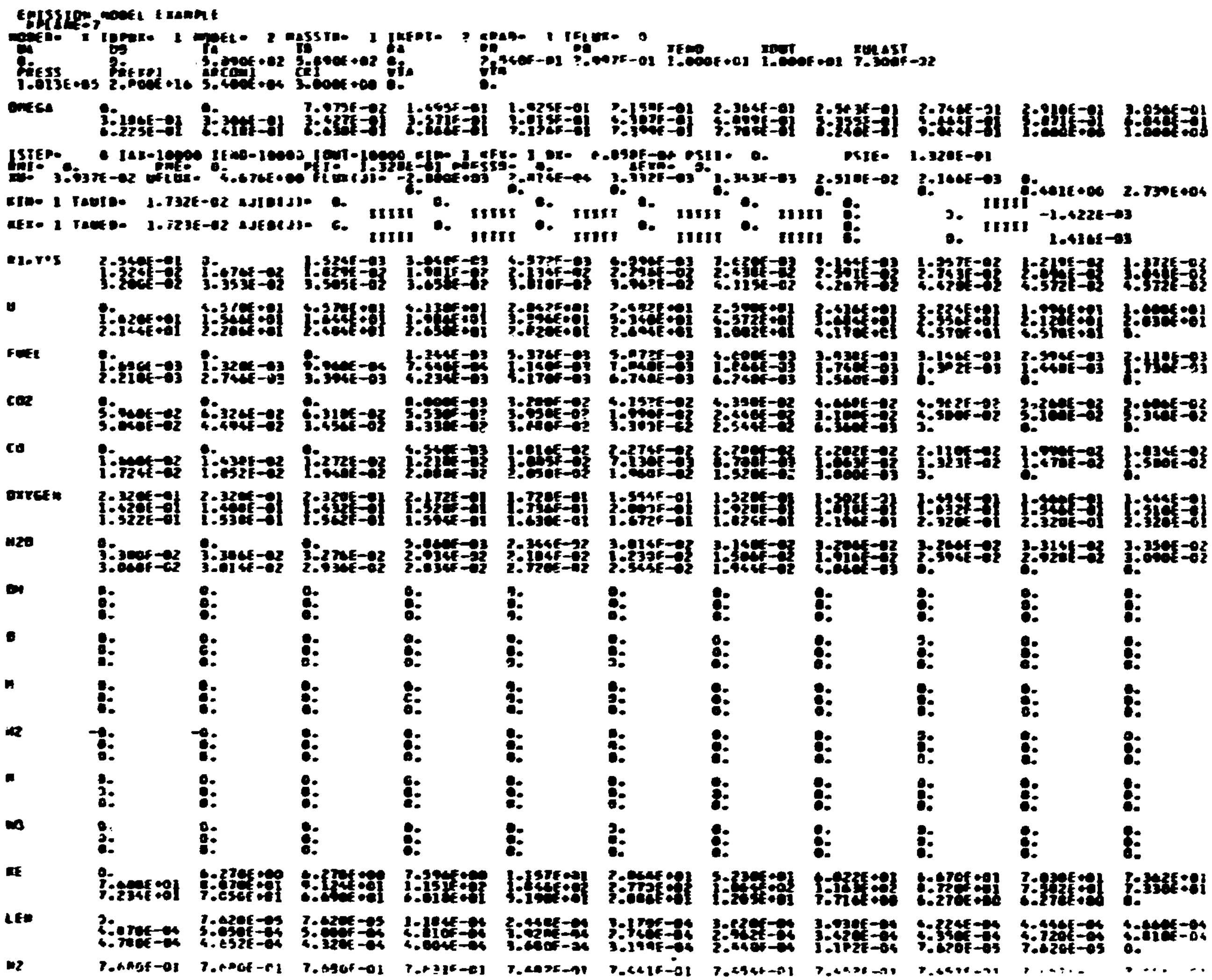


Figure 26. Emission Model Output.

```
ISTEP=  120 IAX=10000 IEND=10000 IOUT=10000 KIN= 1 KEX= 1 RR=  0.          PSII=  0.          PSIE=  1.329E-01
DPI=  0.         DNE=  0.         PEI=  1.320E-01 PRESS= -2.929E-06 AEXP= -4.868E-04
XU=  7.300E-02 UFLUX=  4.855E+00 FLUX(J)= -2.080E+03  2.400E-05  4.493E-03  1.201E-06  2.314E-02  2.456E-03  9.650E-05
                                           1.377E-04  2.902E-04  5.445E-06  1.313E-13  1.092E-30  0.         2.910E+00  2.647E+03
KIN= 1 TAUID=  1.334E-02 AJID(J)=  0.         0.         0.         0.         0.         0.         0.
                                   0.         0.         0.         0.         0.         0.         0.        -1.856E-03
KEX= 1 TAUEG=  1.328E-02 AJED(J)=  0.         0.         0.         0.         0.         0.         0.
                                   0.         0.         0.         0.         0.         0.         0.         1.849E-03

R1,Y'S    2.540E-01  1.756E-04  1.773E-03  3.354E-03  5.075E-03  6.479E-03  8.311E-03  9.971E-03  1.155E-02  1.302E-02  1.434E-02
          1.545E-02  1.639E-02  1.724E-02  1.813E-02  1.962E-02  2.151E-02  2.373E-02  2.554E-02  2.700E-02  2.829E-02  2.944E-02
          3.074E-02  3.219E-02  3.374E-02  3.540E-02  3.715E-02  3.891E-02  4.067E-02  4.235E-02  4.397E-02  4.552E-02  4.570E-02

U         0.         3.764E+01  4.620E+01  4.130E+01  3.234E+01  2.931E+01  2.829E+01  2.713E+01  2.572E+01  2.462E+01  2.459E+01
          2.581E+01  2.770E+01  3.015E+01  3.300E+01  3.738E+01  4.334E+01  4.359E+01  3.664E+01  3.350E+01  3.018E+01  2.792E+01
          2.645E+01  2.702E+01  2.800E+01  2.923E+01  3.019E+01  3.049E+01  3.349E+01  4.701E+01  4.421E+01  3.764E+01  0.

FUEL      3.325E-05  1.234E-05  5.416E-05  1.209E-07  4.970E-08  9.414E-06  4.879E-06  2.437E-06  1.597E-06  1.044E-06  8.859E-07
          5.003E-07  4.668E-07  5.491E-07  7.540E-07  1.333E-06  3.119E-06  3.193E-06  1.663E-06  3.542E-07  8.706E-07  1.048E-06
          1.464E-06  2.050E-06  2.818E-06  4.027E-06  6.991E-06  1.934E-05  5.541E-05  1.416E-03  4.355E-05  1.449E-05  3.902E-05

CO2       4.206E-04  1.468E-04  6.944E-04  1.899E-02  7.563E-02  9.901E-02  9.329E-02  9.325E-02  9.252E-02  9.125E-02  8.851E-02
          8.457E-02  8.021E-02  7.575E-02  7.087E-02  5.374E-02  5.392E-02  5.314E-02  8.023E-02  6.911E-02  7.396E-02  7.837E-02
          8.113E-02  8.197E-02  8.159E-02  8.193E-02  4.965E-02  4.245E-02  6.721E-02  1.944E-02  5.716E-04  1.200E-04  3.462E-04

CO        1.913E-05  8.329E-06  2.993E-05  4.999E-04  1.320E-03  2.574E-03  2.756E-03  2.684E-03  2.521E-03  2.297E-03  1.992E-03
          1.648E-03  1.356E-03  1.111E-03  8.974E-04  6.940E-04  3.904E-04  3.792E-04  5.574E-04  8.406E-04  1.890E-03  1.356E-03
          1.594E-03  1.756E-03  1.895E-03  1.995E-03  2.073E-03  1.961E-03  9.250E-04  4.799E-04  2.691E-05  7.201E-06  1.765E-05

OXYGEN    2.315E-01  2.318E-01  2.312E-01  2.109E-01  1.635E-01  1.253E-01  1.228E-01  1.210E-01  1.218E-01  1.239E-01  1.271E-01
          1.321E-01  1.373E-01  1.427E-01  1.482E-01  1.571E-01  1.673E-01  1.687E-01  1.609E-01  1.516E-01  1.443E-01  1.306E-01
          1.341E-01  1.313E-01  1.295E-01  1.294E-01  1.301E-01  1.336E-01  1.507E-01  2.143E-01  2.314E-01  2.319E-01  2.316E-01

H2O       1.192E-04  4.637E-05  1.960E-04  6.271E-03  2.951E-02  3.541E-02  3.439E-02  3.622E-02  3.501E-02  3.514E-02  3.392E-02
          3.234E-02  3.064E-02  2.895E-02  2.710E-02  2.463E-02  2.955E-02  2.831E-02  2.325E-02  2.634E-02  2.863E-02  3.052E-02
          3.201E-02  3.302E-02  3.348E-02  3.374E-02  3.360E-02  3.775E-02  2.700E-02  4.094E-03  1.552E-04  3.251E-05  9.435E-05

OH        9.578E-07  3.727E-07  1.543E-06  5.212E-05  1.093E-03  1.227E-03  1.033E-03  1.014E-03  1.724E-03  1.635E-03  1.486E-03
          1.314E-03  1.149E-03  9.996E-04  8.596E-04  6.510E-04  4.333E-04  4.229E-04  5.909E-04  8.139E-04  9.999E-04  1.167E-03
          1.309E-03  1.418E-03  1.497E-03  1.535E-03  1.518E-03  1.405E-03  8.403E-04  3.451E-05  1.876E-06  2.375E-07  6.570E-07

O         3.033E-06  9.876E-07  5.079E-06  1.961E-04  1.760E-03  2.953E-03  2.061E-03  2.086E-03  1.893E-03  1.306E-03  1.710E-03
          1.617E-03  1.546E-03  1.486E-03  1.464E-03  1.361E-03  1.212E-03  1.215E-03  1.347E-03  1.493E-03  1.562E-03  1.627E-03
          1.656E-03  1.767E-03  1.890E-03  1.954E-03  1.962E-03  1.914E-03  1.640E-03  1.324E-04  3.508E-06  4.385E-07  2.072E-06

H         2.070E-07  5.045E-08  3.651E-07  1.606E-05  3.720E-05  4.361E-05  4.430E-05  4.195E-05  3.961E-05  3.625E-05  3.368E-05
          3.096E-05  2.922E-05  2.779E-05  2.694E-05  2.560E-05  2.524E-05  2.586E-05  2.700E-05  2.900E-05  2.960E-05  3.095E-05
          3.302E-05  3.465E-05  3.790E-05  4.055E-05  4.071E-05  4.032E-05  3.592E-05  1.269E-05  7.447E-07  3.145E-08  1.381E-07

H2        5.635E-06  2.199E-06  9.079E-06  1.220E-04  4.054E-05  4.001E-05  6.300E-05  6.138E-05  5.753E-05  5.320E-05  4.775E-05
          4.181E-05  3.603E-05  3.268E-05  2.980E-05  2.394E-05  1.889E-05  1.077E-05  2.293E-05  2.901E-05  3.354E-05  3.817E-05
          4.271E-05  4.650E-05  5.071E-05  5.325E-05  5.774E-05  4.974E-05  3.418E-05  1.490E-04  8.733E-06  2.031E-06  5.382E-06

N         2.357E-19  4.692E-21  4.040E-19  2.932E-16  4.394E-13  4.594E-12  4.616E-12  6.006E-12  5.970E-12  4.240E-12  3.293E-12
          1.843E-12  9.416E-13  4.683E-13  2.005E-13  5.040E-14  5.152E-15  4.262E-15  2.511E-14  1.316E-13  3.942E-13  8.850E-13
          1.576E-12  2.194E-12  2.478E-12  2.600E-12  7.544E-12  1.451E-12  1.097E-13  7.634E-17  1.067E-19  5.762E-21  5.600E-20

NO        8.996E-12  1.672E-12  1.632E-11  1.444E-09  5.006E-09  3.355E-07  4.920E-07  5.181E-07  5.019E-07  4.673E-07  3.488E-07
          2.438E-07  1.637E-07  1.067E-07  6.379E-08  2.677E-09  5.384E-09  1.266E-09  6.300E-09  2.973E-09  4.401E-08  7.917E-08
          1.203E-07  1.528E-07  1.643E-07  1.622E-07  1.490E-07  9.726E-08  1.040E-09  2.478E-10  2.731E-12  2.606E-13  1.496E-12

KF        0.         4.759E+00  2.295E+00  4.820E+03  8.478E+09  1.140E+01  1.546E+01  1.048E+01  2.033E+01  2.222E+01  2.667E+01
          3.512E+01  4.501E+01  3.535E+01  6.150E+01  5.637E+01  5.956E+01  5.891E+01  5.144E+01  4.567E+01  3.724E+01  2.953E+01
          2.453E+01  2.247E+01  2.132E+01  1.943E+01  1.627E+01  1.165E+01  8.163E+00  3.911E+00  2.294E+05  4.781E+00  0.

LEN       0.         2.865E-04  1.590E-04  2.089E-04  3.879E-04  5.280E-04  5.979E-04  6.677E-04  7.300E-04  7.856E-04  8.019E-04
          7.745E-04  7.452E-04  7.226E-04  7.002E-04  5.434E-04  5.965E-04  5.790E-04  6.187E-04  6.652E-04  7.883E-04  7.497E-04
          7.735E-04  7.564E-04  7.131E-04  6.580E-04  5.911E-04  5.079E-04  3.776E-04  1.996E-04  1.495E-04  2.853E-04  0.

N2        7.679E-01  7.679E-01  7.679E-01  7.610E-01  7.448E-01  7.415E-01  7.409E-01  7.423E-01  7.435E-01  7.440E-01  7.452E-01
          7.464E-01  7.477E-01  7.470E-01  7.563E-01  7.579E-01  7.545E-01  7.557E-01  7.531E-01  7.597E-01  7.494E-01  7.483E-01
          7.481E-01  7.485E-01  7.501E-01  7.593E-01  7.459E-01  7.442E-01  7.515E-01  7.620E-01  7.676E-01  7.680E-01  7.679E-01

TEMP      5.944E+02  5.910E+02  5.962E+02  7.920E+02  1.416E+03  1.575E+03  1.590E+03  1.590E+03  1.593E+03  1.580E+03  1.552E+03
          1.513E+03  1.470E+03  1.425E+03  1.375E+03  1.302E+03  1.107E+03  1.190E+03  1.269E+03  1.351E+03  1.413E+03  1.463E+03
          1.500E+03  1.522E+03  1.527E+03  1.531E+03  1.570E+03  1.489E+03  1.239E+03  7.554E+02  5.949E+02  5.907E+02  5.936E+02

AMU(I)    3.084E-05  2.175E-04  6.795E-05  9.847E-05  1.395E-04  1.909E-04  2.853E-04  3.663E-04  4.635E-04  5.394E-04  6.150E-04
          7.276E-04  8.456E-04  9.519E-04  1.042E-03  1.097E-03  9.765E-04  8.833E-04  9.933E-04  9.337E-04  7.421E-04  6.553E-04
          5.842E-04  5.250E-04  4.676E-04  3.957E-04  3.095E-04  2.119E-04  1.431E-04  9.290E-05  4.902E-05  2.165E-04  3.081E-05
PLOT AT XU=  7.300E-02, ISTEP=  120

X-AXIS IS Y(I)        ,MAXIMUM VALUE = 4.570E-02
Y-AXES ARE        VELOCITY   FUEL       CO         OXYGEN     TEMP
SYMBOL               U         1          3          4          T
MAXIMUM VALUES   4.621E+01  1.416E-03  2.756E-03  2.315E-01  1.590E+03
```

Figure 27. Emission Model Output.

1 TITLE 80

FUEL INSERTION MODEL EXAMPLE

* ATOM TYPE	** AIR ASSIST	PRIM FLOW NO. (JP4) PPH/$\sqrt{PSI}$	SEC. FLOW NO. (JP4)	CONE ANGLE DEG	AIR ASSIST SHROUD EFF AREA IN^2	PRIM ORIFICE DIA, IN	SEC ORIFICE DIA, IN	
1 →	6 →	11	21	31	41	51	61	71 80
3	1	10.		90.				

2

*ATOMIZER TYPE: 00001 = SIMPLEX
00002 = DUAL ORF
00003 = AIR BLAST

**AIR ASSIST: 00001 = NO ASSIST
00002 = WITH ASSIST

*FOR ATOM TYPE = 00002 (DUAL ORIF) ONLY (LEAVE OUT FOR OTHERS)
INPUT SECONDARY FLOW SCHEDULE

W_S = SECONDARY FUEL FLOW, LB/HR

$\Delta P_S = \Delta P_{SEC.\ ORIF} + \Delta P_{FLOW\ DIVIDER\ VALVE}$, P/D

CRACK POINT FLOW W_{S1}	W_{S2}	W_{S3}	W_{S4}	W_{S5}	
1	11	21	31	41	51

3

CRACK PRESSURE ΔP_1	ΔP_2	ΔP_3	ΔP_4	ΔP_5	
1	11	21	31	41	51

4

*FOR ATOM TYPE = 00003 (AIRBLAST) ONLY (LEAVE OUT FOR OTHERS)

FILMING DIA IN.	NOZZLE AIRFLOW LB/SEC	FLOW AREA IN^2	AIR TEMP °R	
1	11	21	31	
0.5	.05	.2	1060.	

5

Figure 28. Fuel Insertion Model Input (1 of 3)

	*** FUEL TYPE	**** AIR FLOW OPTION	FUEL TEMP °R	FUEL FLOW LB/HR	FUEL ΔP PSI	AIR ASSIST ΔP PSI	AIR ASSIST TEMP °R		
	1 →	6 →	11	21	31	41	51	61	71
6	2	2	520.	60.					

***FUEL TYPE: 00002=JP5, 00004=JP4

****AIR FLOW OPTION: 00001=UNIFORM GAS STREAM, 00002=2-D FIELD OPTION

UNIFORM STREAM OPTION:

	T_{GAS}, °R	V_{GAS}, FPS	P_{GAS}, PSIA	X_{MAX}, IN.	Y_{MAX}, °R			
	1	11	21	31	4	51		
7	.2	.2	14.7	5.0	1.5			
	X_{NOZ} ℄ IN.	Y_{NOZ} ℄ IN.	P_{GAS} PSIA	X_{MAX} IN.	Y_{MAX} IN.			

2-D FIELD OPTION: bottom row of labels above.

CARDS 8 THROUGH 13 SKIPPED IF AIR FLOW OPTION = 00001

IN = NO. OF X-DIR POINTS IN 2-D FIELD
JN = NO. OF Y- DIR POINTS

	IN	JN	(2(I2, 8X))					
8	03	03						

X VALUES (8E10.4) X - LOCATIONS OF GRID POINTS (FT)

9	0.	.2083	.4167					

Y VALUES (8E10.4) Y - LOCATIONS OF GRID POINTS (FT)

10	0.	.0625	.125					

U VALUES (8E10.4) READ ALONG + X LINES STARTING WITH SMALLEST Y VALUE (FT/SEC)

11	30.	75.	100.					
	35.	80.	110.					
	40.	85.	115.					

Figure 28. Fuel Insertion Model Input (2 of 3)

V VALUES (8E10.4) READ ALONG + X LINES STARTING WITH SMALLEST Y VALUE (FT/SEC)

12	0.	0.	0.					

0. 0. 0.

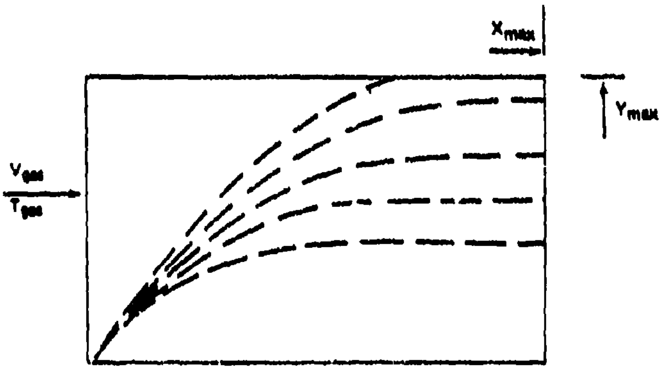
0.	0.	0.					

T VALUES (8E10.4) READ ALONG + X LINES STARTING WITH SMALLEST Y VALUE (DEG. R)

13	1060	1060	1060					

1060 1060 1060

1060	1060	1060					



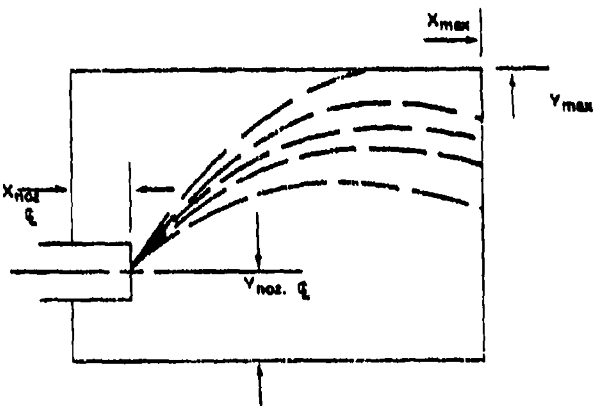


Figure 28. Fuel Insertion Model Input (3 of 3)

nozzle types. The values of Card 7 can have two meanings, depending on the type of flow field. In this case, they give the X and y location of the origin of the spray, the pressure, and limits of the two-dimensional grid. Cards 8 through 13 are required in this example, and it can be seen that only a 3 X 3 grid was used which requires 9 values of U, V, and temperature.

The program output is illustrated in Figures 29 and 30. The first items printed are some of the input quantities, along with the specific gravity and viscosity of the specified fuel. The fuel ΔP and velocity are given next, along with the calculated value of SMD. For each of the five droplets, the locations are then given at the point that selected fractions of the fuel that had evaporated. In this case, droplets 1 and 2 evaporated within the specified boundaries. Figure 30 shows the trajectory output for each of the five droplets. The output consists of a pair of lines, the first giving the X and Y location of the droplet and the second giving the diameter, temperature, velocity, and fraction evaporated.

```
FUEL INSERTION MODEL EXAMPLE

AIRBLAST ATOMIZER, CONE ANGLE =    90.0
WITHOUT AIR ASSIST
FILM DIA, NOZZLE AIRFLOW, FLOW AREA,T35,     .5000     .0500     .7000 1060.0000
 NFUEL IOPT TFUEL PPH DELP DELPSH TSH =     2    2 520.00000  60.00000  -0.00000  -0.00000  -0.00000
ARBITRARY FLOW OPTION, X START, Y START, P GAS, X MAX, Y MAX =     .20000     .20000 147.00000    5.00000    1.50000

SG=   .8260E+00 (BMLS)     VISC FUEL=    .2492E+01 CENTISTOKES

DELTA P (1)=      30.00     PPH (1)=      60.00
DELTA P (2)=       0.0C     PPH (2)=       0.00
DELTA P (V)=       0.00       VFUEL=      74.39
SMD=      41.20

AIR/FUEL MASS RATIO=        3.000 EFF. AIR VELOCITY=

DROPLET  1 E= .10      X1, X2=    .43062    .36682 IN

DROPLET  1 E= .20      X1, X2=    .52314    .40377 IN

DROPLET  1 E= .30      X1, X2=    .50326    .42652 IN

DROPLET  1 E= .40      X1, X2=    .68542    .44366 IN

DROPLET  1 E= .50      X1, X2=    .77486    .45777 IN

DROPLET  1 E= .60      X1, X2=    .87766    .47021 IN

DROPLET  1 E= .70      X1, X2=  1.00161    .48158 IN

DROPLET  1 E= .80      X1, X2=  1.16126    .49217 IN

DROPLET  1 E= .90      X1, X2=  1.38888    .50199 IN

DROPLET  1 E= .95      X1, X2=  1.56262    .50668 IN
DROPLET  1 HAS EVAPORATED

DROPLET  2 E= .10      X1, X2=    .65474    .49756 IN

DROPLET  2 E= .20      X1, X2=    .84873    .56477 IN

DROPLET  2 E= .30      X1, X2=  1.01970    .60716 IN

DROPLET  2 E= .40      X1, X2=  1.19730    .63969 IN

DROPLET  2 E= .50      X1, X2=  1.39640    .66632 IN

DROPLET  2 E= .60      X1, X2=  1.63604    .68880 IN

DROPLET  2 E= .70      X1, X2=  1.94389    .70746 IN

DROPLET  2 E= .80      X1, X2=  2.36680    .72219 IN

DROPLET  2 E= .90      X1, X2=  3.02991    .73325 IN

DROPLET  2 E= .95      X1, X2=  3.56925    .73773 IN
DROPLET  2 HAS EVAPORATED

DROPLET  3 E= .10      X1, X2=    .88633    .61133 IN
```

Figure 29. Fuel Insertion Model Output.

0 - 20 / VOLUME

25.667

X	D	TF	Y	VF	E*100 /
.20	26.	520.	.20	74.	0. /
.24	26.	576.	.23	62.	0. /
.27	26.	617.	.27	54.	1. /
.31	26.	659.	.30	48.	2. /
.36	26.	697.	.33	45.	4. /
.40	26.	729.	.35	42.	7. /
.44	26.	756.	.37	40.	11. /
.49	25.	779.	.39	40.	16. /
.54	25.	797.	.41	40.	22. /
.58	24.	811.	.42	40.	28. /
.63	24.	822.	.43	41.	34. /
.68	23.	831.	.44	42.	40. /
.73	22.	838.	.45	43.	45. /
.78	21.	844.	.46	44.	51. /
.83	21.	849.	.46	45.	56. /
.88	20.	853.	.47	46.	60. /
.93	19.	857.	.48	47.	65. /
.98	18.	860.	.48	47.	68. /
1.03	18.	864.	.48	48.	72. /
1.08	17.	867.	.49	49.	75. /
1.13	16.	870.	.49	50.	78. /
1.18	16.	873.	.49	51.	81. /
1.23	15.	875.	.50	52.	83. /
1.28	14.	878.	.50	53.	86. /

20 - 40 / VOLUME

38.397

X	D	TF	Y	VF	E*100 /
.20	38.	520.	.20	74.	0. /
.24	39.	547.	.23	64.	0. /
.27	39.	573.	.27	57.	9. /
.31	39.	599.	.30	52.	0. /
.35	39.	623.	.33	49.	1. /
.39	39.	646.	.36	47.	1. /
.43	39.	667.	.39	45.	2. /
.48	39.	687.	.41	44.	3. /
.52	39.	705.	.44	43.	5. /
.57	39.	721.	.46	42.	6. /
.61	39.	736.	.48	42.	8. /
.66	39.	750.	.50	42.	10. /
.70	38.	762.	.52	42.	12. /
.75	38.	773.	.53	42.	15. /
.80	38.	783.	.55	43.	17. /
.85	37.	792.	.56	44.	20. /
.89	37.	800.	.58	44.	23. /
.94	37.	806.	.59	45.	26. /
.99	36.	812.	.60	46.	28. /
1.04	36.	818.	.61	47.	31. /
1.09	35.	823.	.62	48.	34. /
1.14	35.	827.	.63	49.	37. /
1.19	34.	831.	.64	50.	40. /
1.24	34.	834.	.65	51.	42. /

40 - 60 / VOLUME

49.616

X	D	TF	Y	VF	E*100 /
.21	49.	520.	.20	74.	0. /
.24	49.	539.	.23	66.	0. /
.27	49.	557.	.27	60.	0. /
.31	49.	574.	.30	55.	0. /
.34	49.	593.	.33	51.	0. /
.39	49.	610.	.36	49.	1. /
.43	49.	627.	.39	47.	1. /
.47	49.	643.	.42	45.	1. /
.52	49.	657.	.44	44.	2. /
.56	49.	671.	.47	44.	2. /
.60	49.	686.	.49	43.	3. /
.65	49.	697.	.51	43.	4. /
.69	49.	708.	.53	43.	5. /
.74	49.	719.	.55	43.	6. /
.79	49.	729.	.57	43.	7. /
.83	49.	739.	.59	43.	9. /
.88	49.	748.	.61	44.	10. /
.93	49.	756.	.63	44.	11. /
.97	48.	764.	.64	45.	13. /
1.02	48.	771.	.66	45.	14. /
1.07	48.	778.	.67	46.	16. /
1.12	48.	784.	.68	47.	17. /
1.17	47.	790.	.70	47.	19. /
1.22	47.	795.	.71	48.	21. /

60 - 80 / VOLUME

59.737

X	D	TF	Y	VF	E*100 /
.20	60.	520.	.20	74.	0. /
.31	60.	561.	.30	57.	0. /
.39	60.	597.	.36	51.	0. /
.47	61.	612.	.42	47.	1. /
.55	61.	635.	.47	45.	1. /
.64	61.	656.	.52	44.	2. /
.73	61.	676.	.57	44.	3. /
.82	61.	694.	.61	44.	4. /
.92	61.	710.	.65	44.	5. /
1.01	60.	724.	.68	45.	7. /
1.10	60.	737.	.71	46.	8. /
1.20	60.	749.	.74	48.	10. /
1.30	60.	760.	.77	49.	12. /
1.39	59.	770.	.79	50.	14. /
1.49	59.	778.	.81	52.	16. /
1.59	59.	786.	.83	54.	18. /
1.69	58.	793.	.85	55.	20. /
1.79	58.	799.	.87	57.	23. /
1.88	57.	805.	.89	58.	25. /
1.98	56.	810.	.90	60.	27. /
2.08	56.	815.	.91	62.	30. /
2.18	55.	819.	.93	63.	32. /
2.28	55.	823.	.94	65.	34. /
2.38	54.	826.	.95	57.	36. /

80 - 100 / VOLUME

78.277 MICRONS

X	D	TF	Y	VF	E*100 /
.20	78.	520.	.20	74.	0. /
.31	79.	547.	.30	59.	0. /
.39	79.	564.	.37	54.	0. /
.47	79.	582.	.43	50.	0. /
.55	79.	598.	.48	47.	0. /
.63	79.	614.	.54	46.	1. /
.72	79.	629.	.58	45.	1. /
.81	80.	643.	.63	45.	1. /
.90	80.	657.	.67	45.	2. /
.99	80.	669.	.71	46.	2. /
1.09	80.	681.	.75	46.	3. /
1.18	80.	691.	.78	47.	4. /
1.28	80.	701.	.81	49.	4. /
1.37	79.	710.	.84	50.	5. /
1.47	79.	719.	.87	51.	6. /
1.56	79.	727.	.89	53.	7. /
1.66	79.	734.	.91	54.	8. /
1.76	79.	741.	.94	56.	9. /
1.86	79.	748.	.96	57.	10. /
1.96	78.	754.	.97	59.	11. /
2.05	78.	760.	.99	60.	12. /
2.15	78.	765.	1.01	62.	13. /
2.25	78.	770.	1.02	63.	14. /
2.35	77.	775.	1.04	65.	15. /

Figure 30. Fuel Insertion Model Output.

REFERENCES

1. Shapiro, Ascher H., "The Dynamics and Thermodynamics of Compressible Fluid Flow, Vol. I", Chapter 8, The Ronald Press Company, New York (1953).

2. Gurevich, M. I., "Theory of Jets in an Ideal Fluid", Pergamon Press, pp 52-59.

3. Hunter, S. C., K. M. Johansen, H. C. Mongia and M. P. Wood, "Advanced, Small, High-Temperature-Rise Combustor Program, Volume II: Analytical Model Derivation and Combustor-Element Rig Tests (Phases I and II)", AD778766 (1974).

4. Williams, F. A., "Combustion Theory", Addison-Wesley Publishing Company, Inc. (1965).

5. Spalding, D. B., "Mixing and Chemical Reaction in Steady Confined Turbulent Flames", Thirteenth Symposium (International) on Combustion, The Combustion Institute, 1971.

6. Hamaker, H. C., "Radiation and Heat Conduction in Light-Scattering Material", Philips Research Report, Vol. 2, pp 55-67, 1947.

7. Patankar, S. V., and D. B. Spalding, "A Computer Model for Three-Dimensional Flow in Furnaces", Fourteenth Symposium (International) on Combustion, The Combustion Institute, 1973.

8. Siddall, R. G., "Flux Methods for the Analysis of Radiant Heat Transfer", Paper presented at the Fourth Symposium on Flames and Industry, 1972.

9. McCreath, C. G. and N. A. Chigier, "Liquid Spray Burning in the Wake of a Stabilizer Disc", Fourteenth Symposium (International) on Combustion, The Combustion Institute (1973).

10. Nuruzzaman, A. S. M., A. B. Hedley, and J. M. Beer, "Combustion of Monosized Droplet Streams in Self-Supporting Flames", Thirteenth Symposium (International) on Combustion, The Combustion Institute (1971).

11. Chigier, N. A., et. al, "Dynamics of Droplets in Burning and Isothermal Sprays", Combustion and Flame, V23 (1974).

12. Natarajan, R., "Experimental Drag Coefficients for Evaporating and Burning Drops at Elevated Pressures", Combustion and Flame, V20 (1973).

13. Rush, J. H. and H. Krier, "Burning of Fuel Droplets at Pressures Greater than Atmospheric", Combustion and Flame V22 (1974).

14. Raghunandan, B. N., and H. S. Mukunda, "The Problem of Liquid Droplet Combustion - Reexamination", Combustion and Flame V30 (1977).

15. Shyu, R. R., C. S. Chen, G. O. Gondie and M. M. Elwakil, "Multi-Component Heavy Fuel Drop Histories in a High Temperature Flow Field", Fuel, V51 (1972).

16. Gordon, S. and B. J. McBride, "Computer Program for Calculation of Complex Chemical Equilibrium Compositions, Rocket Performance, Incident and Reflected Shocks and Chapman-Jouguet Detonations", NASA SP-273 (1971).

17. de Vahl, Davis, and G. D. Mallison, "An Evaluation of Upwind and Central Difference Approximations by a Study of Recirculating Flow", Computers and Fluids (1976).

18. Anon., "Proceedings of the Third AIAA Computational Fluid Dynamics Conference", Albuquerque, New Mexico, June 27-28, 1977.

19. Patankar, S. V., "Numerical Prediction of Three-Dimensional Flows", in Studies in Convection: Theory, Measurement and Application, Volume 1, Edited by B. E. Launder, Academic Press, 1975.

20. Jones, W. P. and B. E. Launder, "The Calculation of Low-Reynolds Number Phenomena with a Two-Equation Model of Turbulence", ASME Paper 72-HT-20, 1971.

21. Patankar, S. V. and D. B. Spalding, "Heat and Mass Transfer in Boundary Layers", Intertext Books, London; 1970.

22. Sanborn, J. W., R. S. Reynolds and H. C. Mongia, "A Quasi-Three-Dimensional Calculation Procedure for Predicting the Performance and Gaseous Emissions of Gas Turbine Combustors", AIAA Paper 76-642, 1976.

23. Mosier, S. A., and R. Roberts, "Low-Power Turbopropulsion Combustor Exhaust Emissions, Volume 3, Analysis", Technical Report AFAPL-TR-73-36, 1974.

24. Edelman, R., J. Boccio and G. Weilerstein, "The Role of Mixing and Kinetics in Combustion Generater NO_x", Paper presented at AICHE Symposium on Control of NO_x Emissions in Direct Combustion Power Sources, 1973.

APPENDIX A
INPUT SHEETS

ANNULUS LOSS MODEL INPUT SHEET

1 TITLE - MUST HAVE FOR EACH CASE — ITER 78, IPIC 79, IDBUG 80

Card 1: | 1 TITLE | 78 ITER | 79 IPIC | 80 IDBUG |

ANNULUS INLET FLOW CARD

Card 2: | 1 H | 3 4 5 NEL | 6 7 8 NELI | 11 W1 | 21 PT1 | 31 TT1 | 41 $BETA_1$ | 51 DP/P | 61 — | 71 — |

DOME INLET FLOW CARD (REQUIRED FOR INTERNAL LINER FLOW ONLY)

Card 3: | 1 2 ID | 6 7 8 NELI | 11 W | 21 PT | 31 TT | 41 BETA | 51 — | 61 — | 71 — |

CONSTANTS CARD

Card 4: | 1 C — | 11 FRIC | 21 BLKF | 31 TANS | 41 CDB | 51 SK | 61 RG | 71 IREAX |

1 Title - Run ident appears on printed output and plot

ITER = 1 some (or all) holes fixed, inlet flow fixed, iterate to get pressure drop.
ITER = 2 some (or all) holes fixed, pressure drop fixed iterate to get inlet flow (input W1 is first guess).

IPIC = 0 no plot
IPIC = 1 plot drawn

IDBUG = 0 output printed after converged solution
IDBUG = 1 output printed after each iteration | Use only to de-
IDBUG = 2 output printed after each element | bugg non-convergence

2 3 NEL = total number of element stations (card 2 only)
NELI = element ID no. (NELEM) at annulus or dome inlet 2 and 3
W_1 and W = air flow at inlet stations, lb/sec
PT_1 and PT = inlet total pressure, PSIA
TT_1 and TT = inlet total temperature, R
$Beta_1$, Beta = swirl angle at inlet
DP/P = total pressure drop, PSIA/PSIA (first guess if ITER = 1) card 2 only

4 FRIC = 0, smooth wall friction factor
FRIC -1, no wall friction
FRIC = roughness factor for rough walls
BLKF = annulus effective area factor (≈ .83 for fully developed turbine flow)
TANS = tangent of flow separation spread angle (.1 recommended)

CDB = drag coefficient of struts across annulus ($1 \rightarrow 1.2$ RECM)
SK = ratio of air specific heats,
RG = air gas constant
IREAX = 0. for reverse flow annular or can combustors
IREAX = 1. for axial flow annular. First data set is for OD panel. Program expects a second set for ID panel

CASE TERMINATION

After last card of case:

o In Column 1, Column 2 blank - case repeated with changes, next card is title card followed by cards with changes from previous run.

oo In Columns 1 and 2, next card is EOF to quit or new title card followed by all cards for complete new case.

		NELEM									
L				XP	RP	XL	RL	CL	T LINER	BLK I	DBK I
L	I			XP	RP	XL	RL	CL	T LINER	BLK I	DBK I
L	C			XP	RP	XL	RL	CL	T RISE		
F	F			W/W1	N HOLES	NHTYP	CD		I SEP		
F	D			W/W2	N HOLES	NHTYP	CD	D HOLES	I SEP		
F	B			W/W1					I SEP		
F	I			WINJ/W	V JET	ANG 1	ABETA		I SEP		

	1	2	345		11	21	31	41	51	61	71	76
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												
39												
40												

PROGRAM 117 INPUT DATA SHEET

INPUT FORMAT FOR ELEMENT CARDS - SHEET 2

NELEM — ALL NUMBERS MUST HAVE DECIMAL POINTS

1	2	3 4 5	11	21	31	41	51	61	71	76
L		0 0 1	XP	RP	XL	RL	CL	T LINER	BLK I	DBK I
L	I	0 0 2	XP	RP	XL	RL	CL	T LINER	BLK I	DBK I
L	C	0 0 3	XP	RP	XL	RL	CL	T RISE	--	--
F	F	0 0 4	W/W1	N HOLES	NHTYP	CD	--	I SEP	--	--
F	D	0 0 5	W/W1	N HOLES	NHTYP	CD	D HOLES	I SEP	--	--
F	B	0 1 0	W/W1	--	--	--	--	I SEP	--	--
F	I	0 2 0	W/INJ/W	V JET	ANGJ	ABETA	--	I SEP	--	--

<u>ELEMENT SPECIFICATION</u>

Flow passage is divided into length (L) and flow (F) elements, element numbers, NELEM, can be in arbitrary order, i.e., 10, 1, 3, 4, 16, 30. The cards are stacked in order from inlet to last F because numbers are arbitrary, a new element can be inserted without renumbering other cards.

<u>L. LENGTH ELEMENTS</u> All Dimensions in Inches

First L card is annulus inlet (CL = 0) - For both external and internal cases.

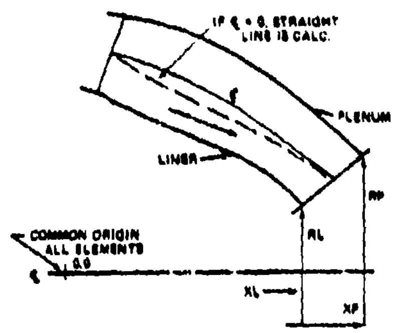
Internal and external flow cases must be run separately

For internal cases, 2nd card is dome inlet (LI) and LC cards are used with T RISE = ΔT due to combustion in this element (no L cards)

For external cases use only L Cards

XL, XP = X COORD to end of element L = Liner
RL, RP = Radius to end of element P = Plenum
(For internal flow XP, RP = OD, XL, RL = ID)
CL = Length of element (optional)
TLIN = Mean wall temp. over CL, °R
If = 0 then TLIN = TT1
BLKI = $\dfrac{\text{Frontal Area of Struts}}{\text{Annulus Area}}$
DBKI = Width of strut

<u>LENGTH ELEMENT</u>



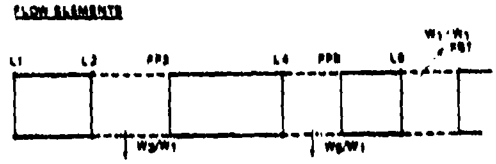
<u>F. ORIFICE FLOW ELEMENT</u>

F Cards are inserted between L cards at points where flow is extracted. Flow conditions into F elem. are those from upstream L elem.

Types: FF = Fixed Flow Ratio, W/W1
FD = Fixed Orf. Diam. (W/W1 is First Guess)
FB = Bleed flow (not included in liner flow)
FI = Internal flow elem. (input to these elements is obtained from an external flow solution)

W/W1 = Orifice Flow/Inlet Flow
NHOLES = No. of Orifices
NHTYP = Hole Type (For CD)
1. Flush Hole, Thin Wall
2. Plunged Hole
3. Cooling Skirt
4. Flush Hole, Thick Wall
5. CD Input
6. Rectangular Hole

<u>FLOW ELEMENTS</u>



CD = DISCH Coefficient (NHTYP = 5 Only)
DHOLES = Hole Diam. (For FD Only)
I SEP = 1, Separation is Reattached
VJET = Jet Injection Velocity, FPS
ANGJ = Jet Injection Angle, Deg.
ABETA = Swirl Angle in Annulus Outside FI Elem.

22 VARIABLE TITLE CARDS (4A10) SAME ORDER AS IMPRINT

1								

CASE TITLE CARD (8A10)

2								

	LP1	MP1	LP1	IPLAX	MODEL	MODER	IPAR	ITRAD
3								

	IU	MODEN	INTAPE	IDW	IRES			
4								

ISOLVE (8(I2, 8X))

	U	V	W	P'	KE	ϵ	Φ	MFU
5								

	MCO	$\tilde{h}$	FX	FY	FZ			

ICTDMA (8(I2, 8X))

	U	V	W	P'	KE	ϵ	Φ	MFU
6								

	MCO	$\tilde{h}$						

IMPRINT (8(I2, 8X))

	U	V	W	PRESS	KE	ℓm	Φ	MFU
7								

TEMP	$\tilde{h}$	Favg	Fx	Fy	Fz	MCO	MH2O

MO2	MCO2	MN2	μEFF	DENSITY	EVAP		

<u>RELAXATION PARAMETERS</u> (8E10.4)

8

U	V	W	P'	KE	ϵ	Φ	MFU

MCO	$\tilde{h}$	Fx	Fy	Fz	PRESS	DENSITY	VISCOS

<u>LAMINAR PRANDTL NUMBERS</u> (8E10.4)

9

U	V	W	P'	KE	ϵ	Φ	MFU

MCO	$\tilde{h}$						

<u>TURBULENT PRANDTL NUMBERS</u> (8E10.4)

10

U	V	W	P'	KE	ϵ	Φ	MFU

MCO	$\tilde{h}$						

X-COORDINATES (1-LP1) (8E10.4)

11

RI Y-COORDINATES (2-MP1) (8E10.4)

12

Z-COORDINATES (1-NP1) (8E10.4)

13

IWEI JWIO (2(I2,8X))

14

IWLI VALUES (8(I2,8X)) (SKIP 15 AND 16 IF IWEI = 2)

15

Card								
	JWLO VALUES (8(I2, 8X))							
16								
	PRESS	DEN	ABSOR	SCATR	AKFAC	ALFAC	(8E10.4)	
17								
	CX	HY	HFU	FUMCO			(8E10.4)	
18								
	PREXP1	ARCON1	CR1	PREXP2	ARCON2	CR2	(8E10.4)	
19								
							(8E10.4)	
	C1	C2	CD	AMU	ERROR	TCYLW	TINLW	TLIP
20								
						(2(I3, 7X), 6(I2, 8X)		
	LASTEP	IJUMP	JSW1	JSW2	NUINJ	NVINJ		
21								
	USW	VSW	SWNO	AFSW	FSW	TSW	(8E10.4)	
22								
	NFNZ	ISPRAY	TFUEL					
23								
	XO	YO	ZO	ALFA	BETA	DELTA	THETA 1	THETA 2
24								
	RSP	WF	SMD	VFUEL	(SKIP 24 IF NFNZ = 00)			

(SKIP CARDS 25 → 30 IF NUINJ = 00)

I - LOCATION OF COOLING SLOTS (8(I2, 8X))

25

J - LOCATION OF COOLING SLOTS (8(I2, 8X))

26

AXIAL SLOT VELOCITY (8E10.4)

27

TANG. SLOT VELOCITY (8E10.4)

28

SLOT FLOW RATE (8E10.4)

29

SLOT TEMPERATURE (8E10.4)

30

(SKIP CARDS 31 → 38 IF NVINJ = 00)

I - LOCATION OF RADIAL INJECTION (8(I2.8X))

31

J - LOCATION OF RADIAL INJECTION (8(I2, 8X))

32

K - LOCATION OF RADIAL INJECTION (8(I2, 8X))

33

INJECTION VELOCITY (8E10.4)

34

INJECTION TURBULENT KINETIC ENERGY (8E10.4)

35								

INJECTION TURBULENT LENGTH SCALE (8E10.4)

36								

INJECTION FLOW RATE (8E10.4)

37								

INJECTION TEMPERATURE (8E10.4)

38								

3D COMBUSTOR PERFORMANCE MODEL
INPUT SHEET DESCRIPTION

Card Set	Description
1	Each card is a heading for a particular three-dimensional array that is printed out. These never change.
2	Case title card
3	LPI - Number of grid nodes in axial (x) dir. MPI - Number of grid nodes in radial (y) dir. NPI - Number of grid nodes in tang. (z) dir. IPLAX - 01 For plane geometry - 02 For axisymmetric geometry MODEL - 01 For laminar viscosity - 02 For K-E viscosity model MODER - 01 For kinetic controlled combustion - 02 For kinetic and turbulence controlled combustion IPAR - 01 For absolute pressure - 02 For relative pressure ITRAD - 01 No radiation - 02 With radiation
4	IU - 01 Input units are international system (i.e., meters, kilograms, degrees kelvin, newtons, joules, radians, seconds or combinations thereof) - 02 User selected input units MODEN - 01 Density is fixed at the value of "Den" on Card 17 - 02 Density calculated from perfect gas law INTAPE - 00 Initial conditions not printed - 08 Initial conditions printed IDW - 00 Inner boundary is axis of symmetry - 01 Inner boundary is wall IRES - 00 This is a new case - 01 This is a restart of previous case
5	An 01 in proper field indicates that this particular variable will be solved for; an 00 indicates that it will not be.
6	Indicates the number of "sweeps" made in the solve routine for each variable.

7	An 01 indicates that this variable will be printed, an 00 indicates that it will not be.	
8	Relaxation parameters for each variable.	
9	Laminar Prandtl numbers for each variable.	
10	Turbulent Prandtl numbers for each variable.	
11	X-coordinates (LPI values)	
12	RI	- Radius of inner boundary Y-coordinates as measured from inner boundary (MP1-1) values. Since Y(1) is <u>always</u> 00, RI is read in its place.
13	Z	- coordinates (NPI values)
14	IWEI	- I-node at which inclined wall ends
	JWIO	- J-node at which inclined wall starts
15	IWLI	- Starting I-nodes of the calculation domain when inclined wall is present
16	JWLO	- Ending J-nodes of the calculation domain when inclined wall is present
17	PRESS	- System pressure
	DEN	- The value of density if option MODEN = 01 is selected
	ABSOR	- Absorption coefficient in radiation model
	SCATR	- Scattering coefficient in radiation model
	AKFAC	- Internally defined turbulent kinetic energies are AKFAC times the appropriate velocity squared
	ALFAC	- Internally defined turbulent length scales are ALFAC times the appropriate distance
18	CX	- Carbon atoms in fuel molecule
	HY	- Hydrogen atoms in fuel molecule
	HFU	- Heat of formation of fuel
	FUMCO	- Initial value assigned to M_{CO}
19	PREXPI	- Preexponent of 1st reaction
	ARCONI	- Activation energy divided by gas constant of 1st reaction (E/R)
	CR1	- Constant in turbulence controlled reaction rate for 1st reaction
	PREXP2	- Preexponent of 2nd reaction

	ARCON2	- Activation energy divided by gas constant of 2nd reaction (E/R)
	CR2	- Constant in turbulence controlled reaction rate for 2nd reaction
20	C1	- Turbulence model constant
	C2	- Turbulence model constant
	CD	- Turbulence model constant
	AMU	- The value of the viscosity if option model = 01 is specified. Also the laminar viscosity used in the "wall functions"
	ERROR	- Program will terminate if total error in mass becomes less than this value
	TCYLW	- Temperature of cylindrical portion of combustor wall
	TINLW	- Temperature of inclined wall portion of combustor and of dome.
	TLIP	- Temperature of cooling slot lip.
21	LASTEP	- Maximum number of iterations
	IJUMP	- Number of iterations between array printout
	JSW1	- J-node at start of dome inlet
	JSW2	- J-node at end of dome inlet
	NUINJ	- Number of axial injection points (cooling slots)
	NUINJ	- Number of radial injection points
22	USW	- Axial velocity of dome inlet
	VSW	- Radial velocity of dome inlet
	SWNO	- Ratio of tangential to axial velocity at dome inlet
	AFSW	- Flow rate of fuel and air through dome inlet
	FSW	- Flow rate of fuel through dome inlet
	TSW	- Temperature at dome inlet
23	NFNZ	- 00 No liquid fuel nozzle
		- 01 Liquid fuel nozzle present
	ISPRAY	- Droplet evaporation routine is called every ISPRAY iterations
	TFUEL	- Initial temperature of liquid fuel
24	XO	- X-location of origin of fuel nozzle spray
	YO	- Y-location of origin of fuel nozzle spray
	ZO	- Z-location of origin of fuel nozzle spray
	ALFA	- Nozzle cone angle
	BETA	- Nozzle back angle
	DELTA	- Nozzle down angle
	THETA1	- Initial spray cone segment angle
	THETA2	- Final spray cone segment angle

RSP - Number of spray cone rays
WF - Fuel flow rate
SMD - Sauter mean diameter
VFUEL - Initial fuel droplet velocity

25 I node location of cooling slots

26 J node location of cooling slots

27 Cooling slot axial velocity

28 Cooling slot tangential velocity

29 Cooling slot mass flow rate

30 Cooling slot temperature

31 I node location of radial injection

32 J node location of radial injection

33 K node location of radial injection

34 Radial injection velocity

35 Radial injection turbulent kinetic energy

36 Radial injection turbulence length scale

37 Radial injection mass flow rate

38 Radial Injection temperature

LINER COOLING MODEL INPUT SHEET

CASE TITLE (12A6)

1

CASE TITLE (12A6)

(8(I2, 8X)

2

N	KRAD	MASSTR	ISWRL	MODEL	INERT	IFLUX	ITEMP

(5(I5.5X)

3

NSTAT	NPROF	NPLOT	ITEST	LASTEP			

(8E10.4)

4

XU	XULAST	FRA	XEND	XOUT	PRESS	POWER	

(I2)

5

NBP							

(8E10.4)

6

X_1	RI_1	RE_1	X_2	RI_2	RE_2	X_3	RI_3

(8E10.4)

RE_3	X_4	RI_4	RE_4	X_5	RI_5	RE_5...	

(8E10.4)

7

RA	RB	RD					

NAME LIST

8	$INPUT							$

UA UD (8E10.4)

9								

F2A F2D TA TD T_{wall} (8E10.4)

10								

NIN (I2)

11								

Y VALUES (8E10.4)

12								

U VALUES (8E10.4)

13								

(8E10.4)

14								

TEMPERATURE VALUES (8E10.4)

15								

MFU VALUES (8E10.4)

16								

PHI VALUES (8E10.4)

17								

MCO VALUES (8E10.4)

18								

TURBULENT KINETIC ENERGY (8E10.4)

19								

TURBULENCE LENGTH SCALE (8E10.4)

20								

(8E10.4)

	$VELA_I$	$VELA_O$	TAN_I	TAN_O	PR_I	PR_O		
21								

(I2, 8X, 7E10.4)

	NFNZ	XDP	YDP	UF	VF	SMD	WF	TFUEL
22								

LINER COOLING MODEL
INPUT SHEET DESCRIPTION

Card Set	Description	
1	Case title cards	
2	N	- Number of cross stream intervals
	KRAD	- 00 For plane geometry 01 For axisymmetric geometry
	MASSTR	- 00 Species equations not solved 01 Species equations solved
	ISWRL	- 00 Always
	MODEL	- 01 Laminar viscosity 02 Two-equation K-E viscosity model
	INERT	- 01 Species are inert 02 Species will react
	IFLUX	- 00 Wall adiabatic 01 Wall temperature calculated
	ITEMP	- 00 Isothermal 01 Enthalpy solved
3	NSTAT	- Number of steps between printout of output variables
	NPROF	- Number of steps between printout of output variables and profiles
	NPLOT	- Number of steps between line-printer plots
	ITEST	- 00 No extra printout 01 Extra printout
	LASTEP	- Maximum number of marching steps
4	XU	- Initial X-location
	XULAST	- Final X-location
	FRA	- Fraction of grid height to be used as step size
	XEND	- X-location of end of inner wall
	XOUT	- X-location of end of outer wall
	PRESS	- Pressure
	POWER	- Control for node spacing
5	NBP	- Number of boundary pairs
6	X_i	- X-Location at which boundary is specified
	RI_i	- Inner boundary radius
	RE_i	- Outer boundary radius
7	RA	- Radius of axis of symmetry
	RB	- Inner boundary radius at initial X-location
	RD	- Outer boundary radius at initial X-location

Card	Variable	Description
8	Namelist, see page 158 for variables	
9	UA	- Axial velocity at "free" inner boundary
	UD	- Axial velocity at "free" outer boundary
10	F2A	- Fuel mass fraction at "free" inner boundary
	F2D	- Fuel mass fraction at "free" outer boundary
	TA	- Temperature at "free" inner boundary
	TD	- Temperature at "free" outer boundary
	TWALL	- Wall temperature
11	NIN	- Number of points on input initial profile
12	Y-values of input initial profile (NIN values)	
13	U-values of input initial profile	
14	Blank card(s)	
15	Temperature values of input initial profile	
16	MFU values of input initial profile	
17	Total fuel values of input initial profile	
18	M_{CO} values of input initial profile	
19	KE values of input initial profile (Read only if KREAD = 1)	
20	ℓm Values of input initial profile (Read only if KREAD = 1)	
21	$VELA_I$	- Inner annulus velocity
	$VELA_O$	- Outer annulus velocity
	TAN_I	- Inner annulus temperature
	TAN_O	- Outer annulus temperature
	PR_I	- Radius of inner plenum
	PR_O	- Radius of outer plenum
22	NFNZ	- 00 No fuel nozzle 01 Fuel nozzle present
	XDP	- X-location of fuel nozzle
	YDP	- Y-location of fuel nozzle
	UF	- Axial velocity of fuel droplets
	VF	- Radial velocity of fuel droplets
	SMD	- Sauter mean diameter
	WF	- Fuel mass flow rate
	TFUEL	- Fuel temperature

LINER COOLING MODEL
NAMELIST INPUT

VBL	Value	Description
IUTRAP	2	Test for negative U's, see STRIDE(2)
ULIM	0.05	Entrainment control
PEILIM	0.01	Max. fractional mass flow change per step
AFAC	0.2	Relaxation on duct area deviation
AEXDLM	0.02	Max. duct area fractional deviation per step
NOVEL	2	01-U not solved for, 02-solve for U
ARCON1	28500	Activation energy divided by gas constant for fuel reaction
PREXP1	5E + 15	Preexponent for fuel reaction
CR1	6.0	Eddy breakup constant for fuel reaction
ARCON2	12500	Activation energy divided by gas constant for CO reaction
PREXP2	6E + 8	Preexponent for CO reaction
CR2	4.0	Eddy breakup constant for CO reaction
CP	1048	Specific heat
IPDDX	1	01 - Std genmix pressure grad. calculation 02 - "Grid filling duct" version
C1	1.42	Turb. Constant
C2	1.92	Turb. Constant
CD	0.09	Turb. Constant
C2VT	0.36	Turb. Constant
AKFAC	0.03	Factor for internally generated kinetic energy profiles, KE = AKFAC*U^2
ALFAC	0.02	Factor for internally generated length scale profiles, ℓm = ALFAC*ΔY
PREF	--	Turbulent Prandtl numbers
CX	1.0	Molecular carbon value of fuel
HY	4.0	Molecular hydrogen value of fuel
HFU	-49317	Heat of formation of fuel
MODER	2	1 - Kinetic only, 02 - Kinetic + Diffusion
ITHIN	1	Thins output profiles by printing every ITHIN value
KREAD	0	0 - K & E profiles generated internally 1 - K & ℓm read in
URAT	0.83	Cooling slot velocity shape factor
ABSOR	0.1	Absorption coefficient in radiation model
EMISW	0.8	Emissivity of liner wall

TRANSITION MIXING MODEL INPUT SHEET

CASE TITLE CARD (12A6)

1

CASE TITLE CARD (12A6)

(8(I2, 8X))

2

N	KRAD	MASSTR	ISWRL	MODEL	INERT	IFLUX	ITEMP

(5(I5, 5X))

3

NSTAT	NPROF	NPLOT	ITEST	LASTEP			

(8E10.4)

4

ZUI	ZUE	ZULAST	FRA	ZEND	ZOUT	PRESS	POWER

(8(I2, 8X))

5

NBP	ICURV	NRCVI	NRCVE				

(8E10.4)

6

RI_1	XI_1	RI_2	XI_2	RI_3	XI_3	RI_4	$XI_4 \ldots$

(8E10.4)

RE_1	XE_1	RE_2	XE_2	RE_3	XE_3	RE_4	$XE_4 \ldots$

(8E10.4)

7

ZI_1	$RCVI_1$	ZI_2	$RCVI_2$	ZI_3	$RCVI_3$	ZI_4	$RCVI_4 \ldots$

(8E10.4)

ZE_1	$RCVE_1$	ZE_2	$RCVE_2$	ZE_3	$RCVE_3$	ZE_4	$RCVE_4$...

8 (8E10.4)

RA	RB	RD					

9 NAMELIST

$INPUT							$

10 (8E10.4)

UA	UD						

11 (8E10.4)

F2A	F2D	TA	TD	T_{wall}			

12 (I2)

NIN							

13 Y VALUES (8E10.4)

14 U VALUES (8E10.4)

15

16 TEMPERATURE VALUES (8E10.4)

17

18

19

TURBULENT KINETIC ENERGY (8E10.4)

20

TURBULENCE LENGTH SCALE (8E10.4)

21

TRANSITION MIXING MODEL
INPUT SHEET DESCRIPTION

Card Set	Description	
1	Case title cards	
2	N	- Number of cross stream intervals
	KRAD	- 00 For plane geometry 01 For axisymmetric geometry
	MASSTR	- 00 Always
	ISWRL	- 00 Always
	MODEL	- 01 Laminar viscosity 02 Two-equation K-E viscosity model
	INERT	- 01 Always
	IFLUX	- 00 Walls are adiabatic 01 Wall temperature is specified
	ITEMP	- 00 Isothermal 01 Enthalpy solved
3	[illegible]TAT	- Number of steps between printout of output variables
	NPROF	- Number of steps between printout of output variables and profiles
	NPLOT	- Number of steps between line-printer plots
	ITEST	- 00 No extra printout 01 Extra printout
	LASTEP	- Maximum number of marching steps
4	ZUI	- Initial Z-location on inner boundary
	ZUE	- Initial Z-location on outer boundary
	ZULAST	- Final Z location
	FRA	- Fraction of grid height to be used as step size
	ZEND	- Z-location of end of inner wall
	ZOUT	- Z-location of end of outer wall
	PRESS	- Pressure
	POWER	- Control for node spacing
5	NBP	- Number of boundary pairs
	ICURV	- 00 No radius of curvature effects 01 Radius of curvature effects
	NRCVI	- Number of radius of curvature points specified on inner boundary
	NRCVE	- Number of radius of curvature points specified on outer boundary
6	RI_i	- Inner boundary radius
	XI_i	- Inner boundary X-location
	RE_i	- Outer boundary radius
	XE_i	- Outer boundary X-location

7 ZI_i - Z-location on inner boundary at which radius of curvature is specified

$RCVI_i$ - Radius of curvature of inner boundary

ZE_i - Z-location on outer boundary at which radius of curvature is specified

$RCVE_i$ - Radius of curvature of outer boundary

8 RA - Radius of axis of symmetry

RB - Inner boundary radius at initial Z-location

RD - Outer boundary radius at initial Z-location

9 Namelist, see page 164 for variables

10 UA - Axial velocity at "free" inner boundary

UD - Axial velocity at "free" outer boundary

11 F2A - Fuel mass fraction at "free" inner boundary

F2D - Fuel mass fraction at "free" outer boundary

TA - Temperature at "free" inner boundary

TD - Temperature at "free" outer boundary

TWALL - Wall temperature

12 NIN - Number of points on input initial profile

13 Y values of input initial profile (NIN values)

14 U values of input initial profile

15 Blank card(s)

16 Temperature values of input initial profile

17 Blank card(s)

18 Blank card(s)

19 Blank card(s)

20 KE values of input initial profile
(Read only if KREAD = 1)

21 ℓm values of input initial profile
(Read only if KREAD = 1)

TRANSITION MIXING MODEL
NAMELIST INPUT

VBL	Value	Description
IUTRAP	2	Test for negative U's, see STRIDE(2)
ULIM	0.05	Entrainment control
PEILIM	0.01	Max. fractional mass flow change per step
AFAC	0.2	Relaxation on duct area deviation
AEXDLM	0.02	Max. duct area fractional deviation per step
NOVEL	2	01 - U not solved for, 02 - solve for U
ARCON1	28500	Activation energy divided by gas constant for fuel reaction
PREXP1	5E + 15	Preexponent for fuel reaction
CR1	6.0	Eddy break-up constant for fuel reaction
ARCON2	12500	Activation energy divided by gas constant for CO reaction
PREXP2	6E + 8	Preexponent for CO reaction
CR2	6.0	Eddy break-up constant for CO reaction
CP	1255	Specific heat
IDPDX	01	01 - Std genmix pressure grad. calculation 02 - "grid filling duct" version
C1	1.42	Turb. Constant
C2	1.92	Turb. Constant
CD	0.09	Turb. Constant
C2VT	0.36	Turb. Constant
AKFAC	0.03	Factor for internally generated turb. kinetic energy profiles, $KE = AKFAC*U^2$
ALFAC	0.02	Factor for internally generated length scale profiles, $\ell m = ALFAC*\Delta Y$
PREF	--	Turbulent Prandtl numbers
CX	1.0	Molecular carbon value of fuel
HY	4.0	Molecular hydrogen value of fuel
HFU	4E + 7	Heat of combustion of fuel
MODER	2	01 - Kinetic only, 02 - Kinetic + Diffusion
ITHIN	1	Thins output profiles by printing every ITHIN value
KREAD	0	00 - KE & ℓm profiles generated internally 01 - KE & ℓm read in

EMISSIONS MODEL INPUT SHEET

CASE TITLE CARD (12A6)

1								

CASE TITLE CARD (12A6)

(8(I2, 8X))

	N	KRAD	MASSTR	ISWRL	MODEL	INERT	IFLUX	ITEMP
2								

(5(I5, 5X))

	NSTAT	NPROF	NPLOT	ITEST	LASTEP			
3								

(8E10.4)

	XU	XULAST	FRA	XEND	XOUT	PRESS	POWER	
4								

(I2)

	NBP							
5								

	X_1	RI_1	RE_1	X_2	RI_2	RE_2	X_3	RI_3
6								

(8E10.4)

RE_3	X_4	RI_4	RE_4	X_5	RI_5	RE ...	

(8E10.4)

	RA	RB	RD					
7								

Card	Field 1	Field 2	Field 3	Field 4	Field 5	Field 6	Field 7	Field 8	Format
	NAMELIST								
8	$INPUT							$	
9	UA	UD	VTA	VTD					(8E10.4)
10	F2A	F2D	TA	TD	T_{wall}				(8E10.4)
11	NIN	NUI	NUE	NVI	NVE				(5(I2, 8X))
12	Y VALUES								(8E10.4)
13	U VALUES								(8E10.4)
14	Vθ VALUES								(8E10.4)
15	TEMPERATURE VALUES								(8E10.4)
16	MFU VALUES								(8E10.4)
17	MCO_2 VALUES								(8E10.4)

MCO VALUES (8E10.4)

18

MOX VALUES (8E10.4)

19

MH_2O VALUES (8E10.4)

20

MH_2 VALUES (8E10.4)

21

TURBULENT KINETIC ENERGY (8E10.4)

22

TURBULENCE LENGTH SCALE (8E10.4)

23

SKIP FOLLOWING CARD SET IF NUI = 0

X - LOC. OF INTERNAL COOLING SLOTS (8E10.4)

24

LIP LENGTH OF INTERNAL COOLING SLOTS (8E10.4)

25

U - VELOCITY OF INTERNAL COOLING SLOTS (8E10.4)

26

VT - VELOCITY OF INTERNAL COOLING SLOTS (8E10.4)

27

TEMPERATURE OF INTERNAL COOLING SLOTS (8E10.4)

FLOW RATE OF INTERNAL COOLING SLOTS (8E10.4)

29								

SLOT HEIGHT OF INTERNAL COOLING SLOTS (8E10.4)

30								

SLOT TO METERING AREA RATIO FOR INT SLOTS (8E10.4)

31								

SKIP FOLLOWING CARD SET IF NUE = 0

X-LOC OF EXTERNAL COOLING SLOTS (8E10.4)

32								

LIP LENGTH OF EXTERNAL COOLING SLOTS (8E10.4)

33								

U - VELOCITY OF EXTERNAL COOLING SLOTS (8E10.4)

34								

V_T - VELOCITY OF EXTERNAL COOLING SLOTS (8E10.4)

35								

TEMPERATURE OF EXTERNAL COOLING SLOTS (8E10.4)

36

FLOW RATE OF EXTERNAL COOLING SLOTS (8E10.4)

37

SLOT HEIGHT OF EXTERNAL COOLING SLOTS (8E10.4)

38

SLOT TO METERING AREA RATIO FOR EXT SLOTS (8E10.4)

39

SKIP FOLLOWING CARD SET IF NVI = 0

X - LOC OF INTERNAL RADIAL INJECTION (8E10.4)

40

U - VELOCITY OF INTERNAL RADIAL INJECTION (8E10.4)

41

V - VELOCITY OF INTERNAL RADIAL INJECTION (8E10.4)

42

VT - VELOCITY OF INTERNAL RADIAL INJECTION (8E10.4)

43

TEMPERATURE OF INTERNAL RADIAL INJECTION (8E10.4)

44

FLOW RATE OF INTERNAL RADIAL INJECTION (8E10.4)

45

SKIP FOLLOWING CARD SET IF NVE = 0

X - LOC. OF EXTERNAL RADIAL INJECTION (8E10.4)

46

U - VELOCITY OF EXTERNAL RADIAL INJECTION (8E10.4)

47

V - VELOCITY OF EXTERNAL RADIAL INJECTION (8E10.4)

48

VT - VELOCITY OF EXTERNAL RADIAL INJECTION (8E10.4)

49

TEMPERATURE OF EXTERNAL RADIAL INJECTION (8E10.4)

50

FLOW RATE OF EXTERNAL RADIAL INJECTION (8E10.4)

51

EMISSIONS MODEL
INPUT SHEET DESCRIPTION

Card Set	Description	
1	Case title cards	
2	N	- Number of cross stream intervals
	KRAD	- 00 For plane geometry 01 For axisymmetric geometry
	MASSTR	- 00 Species equations not solved 01 Species equations solved
	ISWRL	- 00 Swirl velocity not solved 01 Swirl velocity solved
	MODEL	- 01 Laminar viscosity 02 Two-equation, K-E, viscosity model
	INERT	- 01 Species are inert 02 Species will react
	IFLUX	- 00 Wall adiabatic 01 Wall temperature specified
	ITEMP	- 00 Isothermal 01 Enthalpy solved
3	NSTAT	- Number of steps between printout of output variables
	NPROF	- Number of steps between printout of output variables and profiles
	NPLOT	- Number of steps between line printer plots
	ITEST	- 00 No extra printout 01 Extra printout
	LASTEP	- Maximum number of marching steps
4	XU	- Initial X location
	XULAST	- Final X location
	FRA	- Fraction of grid height to be used as step size
	XEND	- X location of end of inner wall
	XOUT	- X location of end of outer wall
	PRESS	- Pressure
	POWER	- Control for node spacing
5	NBP	- Number of boundary pairs
6	X_i	- X location at which boundary is specified
	RI_i	- Inner boundary radius
	RE_i	- Outer boundary radius
7	RA	- Radius of axis of symmetry
	RB	- Inner boundary radius at initial X-location
	RD	- Outer boundary radius at initial X-location

8	Namelist, see page 174 for variables	
9	UA	- Axial velocity at "free" inner boundary
	UD	- Axial velocity at "free" outer boundary
	VTA	- Tang. velocity at "free" inner boundary
	VTD	- Tang. velocity at "free" outer boundary
10	F2A	- Fuel mass fraction at "free" inner boundary
	F2D	- Fuel mass fraction at "free" outer boundary
	TA	- Temperature at "free" inner boundary
	TD	- Temperature at "free" outer boundary
	TWALL	- Wall temperature
11	NIN	- Number of points on the input initial profile
	NUI	- Number of cooling slots on inner boundary
	NUE	- Number of cooling slots on outer boundary
	NVI	- Number of radial injection points on inner boundary
	NVE	- Number of radial injection points on outer boundary
12	Y values of input initial profile (NIN values)	
13	U values of input initial profile	
14	V_θ values of input initial profile	
15	Temperature values of input initial profile	
16	M_{FU} values of input initial profile	
17	M_{CO2} values of input initial profile	
18	M_{CO} values of input initial profile	
19	M_{OX} values of input initial profile	
20	M_{H2O} values of input initial profile	
21	M_{H2} values of input initial profile	
22	KE values of input initial profile (Read only if KREAD = 1)	
23	ℓm values of input initial profile (Read only if KREAD = 1)	
24 to 31	Information pertaining to cooling slots on inner boundary	

32 to 39 Information pertaining to cooling slots on outer boundary

40 to 45 Information pertaining to radial injections on inner boundary

46 to 51 Information pertaining to radial injections on outer boundary

EMISSIONS MODEL
NAMELIST INPUT

VBL	Value	Description
IUTRAP	2	Test for negative U's, see STRIDE(2)
ULIM	0.05	Entrainment control
PEILIM	0.01	Max. fractional mass flow change per step
AFAC	0.2	Relaxation on duct area deviation
AEXDLM	0.02	Max. duct area fractional deviation per step
NOVEL	2	01 - U not solved for, 02 - Solve for U
ARCON1	28500	Activation energy for fuel reaction
PREXP1	5E + 15	Preexponent for fuel reaction
CR1	6.0	Eddy breakup constant for fuel reaction
CP	1048	Specific heat
IPDDX	1	01 - Std genmix pressure grad. calculation 02 - "grid filling duct" version
C1	1.42	Turb. Constant
C2	1.92	Turb. Constant
CD	0.09	Turb. Constant
C2VT	0.36	Turb. Constant
AKFAC	0.03	Factor for internally generated kinetic energy profiles, KE = AKFAC*U
ALFAC	0.02	Factor for internally generated length scale profiles, ℓm = ALFAC*ΔY
PREF	--	Turbulent Prandtl numbers
CX	1.0	Molecular carbon value of fuel
HY	4.0	Molecular hydrogen value of fuel
HFU	-49317	Heat of formation of fuel
MODER	2	1 - Kinetic only, 02 - Kinetic + Diffusion
ITHIN	1	Thins output profiles by printing every ITHIN value
KREAD	0	0 - K & E profiles generated internally 1 - K & ℓm read in
URAT	0.83	Cooling slot velocity shape factor
TERM1	0.1	Control on specie equation step size
TERM2	1.E-4	Control on specie equation step size
ISMAX	500	Maximum specie equation steps
EFU	1.0	Power on fuel in fuel reaction rate
E_{O2}	0.5	Power on O_2 in fuel reaction rate
E_{H_2O}	0.5	Power on H_2O in fuel reaction rate
ERO	2.0	Power on density in fuel reaction rate
EPR	0.0	Power on pressure in fuel reaction rate

FUEL INSERTION MODEL INPUT

1 TITLE 80

Card 2

* ATOM TYPE	** AIR ASSIST	PRIM FLOW NO. (JP4) PPH/$\sqrt{PSI}$	SEC. FLOW NO. (JP4)	CONE ANGLE DEG	AIR ASSIST SHROUD EFF AREA IN^2	PRIM ORIFICE DIA, IN	SEC ORIFICE DIA, IN
1 → 6	→ 11	21	31	41	51	61	71 – 80

*ATOMIZER TYPE: 00001 = SIMPLEX
00002 = DUAL ORF
00003 = AIR BLAST

**AIR ASSIST: 00001 = NO ASSIST
00002 = WITH ASSIST

*FOR ATOM TYPE = 00002 (DUAL ORIF) ONLY (LEAVE OUT FOR OTHERS)
INPUT SECONDARY FLOW SCHEDULE

W_S = SECONDARY FUEL FLOW, LB/HR

$\Delta P_S = \Delta P_{SEC.\ ORIF} + \Delta P_{FLOW\ DIVIDER\ VALVE}$, P/D

Card 3

CRACK POINT FLOW W_{S1}	W_{S2}	W_{S3}	W_{S4}	W_{S5}	
1	11	21	31	41	51

Card 4

CRACK PRESSURE ΔP_1	ΔP_2	ΔP_3	ΔP_4	ΔP_5	
1	11	21	31	41	51

*FOR ATOM TYPE = 00003 (AIRBLAST) ONLY (LEAVE OUT FOR OTHERS)

Card 5

FILMING DIA IN.	NOZZLE AIRFLOW LB/SEC	FLOW AREA IN^2	AIR TEMP °R	
1	11	21	31	

	*** FUEL TYPE	**** AIR FLOW OPTION	FUEL TEMP °R	FUEL FLOW LB/HR	FUEL ΔP PSI	AIR ASSIST ΔP PSI	AIR ASSIST TEMP °R		
Column	1 →	6 →	11	21	31	41	51	61	71
6									

***FUEL TYPE: 0.00002=JP5, 0.00004=JP4

****AIR FLOW OPTION: 0.00001=UNIFORM GAS STREAM, 0.00002=2-D FIELD OPTION

	Columns 1–10	Columns 11–20	Columns 21–30	Columns 31–40	Columns 41–50	Columns 51–60	Columns 61–70	Columns 71–80
UNIFORM STREAM OPTION	T_{GAS}, °R	V_{GAS}, FPS	P_{GAS}, PSIA	X_{MAX}, IN.	Y_{MAX}, °R			
Column	1	11	21	31	4	51		
7								
Z-D FIELD OPTION	X_{NOZ} ℄ IN.	Y_{NOZ} ℄ IN.	P_{GAS} PSIA	X_{MAX} IN.	Y_{MAX} IN.			

CARDS 8 THROUGH 13 SKIPPED IF AIR FLOW OPTION = 00001

IN = NO. OF X-DIR POINTS IN 2-D FIELD
JN = NO. OF Y- DIR POINTS

	Columns 1–10	Columns 11–20	Columns 21–30	Columns 31–40	Columns 41–50	Columns 51–60	Columns 61–70	Columns 71–80
Format	IN	JN	(2(I2, 8X))					
8								

X VALUES (8E10.4) X - LOCATIONS OF GRID POINTS (FT)

	Columns 1–10	Columns 11–20	Columns 21–30	Columns 31–40	Columns 41–50	Columns 51–60	Columns 61–70	Columns 71–80
9								

Y VALUES (8E10.4) Y - LOCATIONS OF GRID POINTS (FT)

	Columns 1–10	Columns 11–20	Columns 21–30	Columns 31–40	Columns 41–50	Columns 51–60	Columns 61–70	Columns 71–80
10								

U VALUES (8E10.4) READ ALONG + X LINES STARTING WITH SMALLEST Y VALUE (FT/SEC)

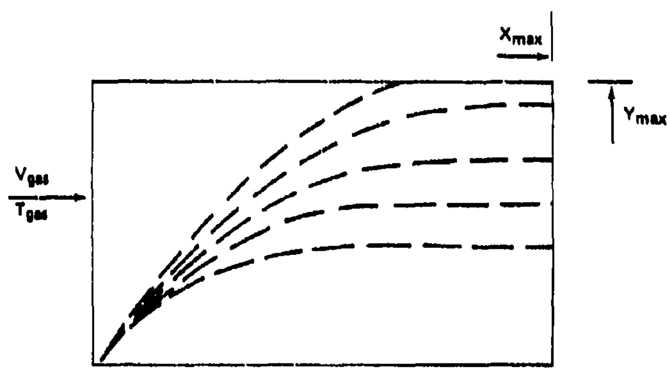
	Columns 1–10	Columns 11–20	Columns 21–30	Columns 31–40	Columns 41–50	Columns 51–60	Columns 61–70	Columns 71–80
11								

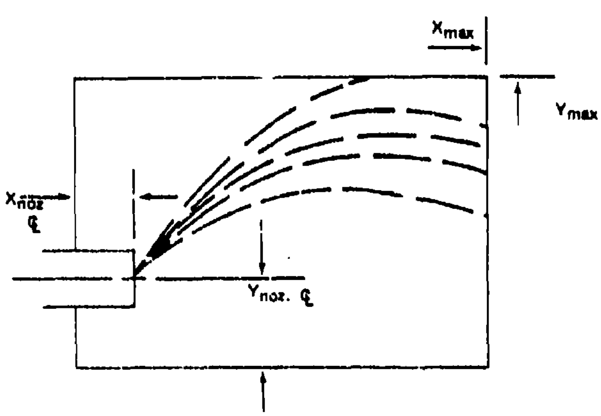
V VALUES (8E10.4) READ ALONG + X LINES STARTING WITH SMALLEST Y VALUE (FT/SEC)

12								

T VALUES (8E10.4) READ ALONG + X LINES STARTING WITH SMALLEST Y VALUE (DEG. R)

13								





APPENDIX B

LISTING OF ANNULUS LOSS MODEL

```
PROGRAM MAIN        73/74    OPT=0 TRACE                    FTN 4.6+439          08/24/79  07.59.39        PAGE    1

        PROGRAM MAIN (INPUT=65,OUTPUT=513,TAPE60=INPUT,TAPE61=OUTPUT,         MA        2
       1  TAPE4=519,TAPE7=519)                                                MA        3
        COMMON/CPICT/XMO,YMO,XFV,YFV,XGV,YGV,XRB(080),YBR(080),XG,YG,         CD1       2
       1  SIZE,XTI,YTI,XMOVE,YMOVE,DATA(12),PXYL(1,1)                         CD1       3
        COMMON/INPUTC/DP,BLKF,SK,RE,FRIC,TANS,COR,NFL,TITLE(10),NELTOT,       CD2       2
       +  NELEM(080),NETYP(080),R0(080),XR(080),XI(080),CL(080),RI(080),      CD2       3
       2  TLIN(080),ALKI(080),DALK(080),WRPCT(080),NHOLES(080),NHTYP(080),    CD2       4
       3  ISEP(080),ICBUG,NFA(080),TPIC,ABETA(080),SIGM,SIGM2,IRUN,ICASE      CD2       5
        COMMON/OUTPUT/PTOIS,CDOV,WCOMPT,CUMGA,CUMWJ,RR(080),H(080),           CD2       6
       1  AX(080),BLKW(080),BLKS(080),FAX(080),FAF(080),BETA(080),PS(080),    CD2       7
       2  W(080),TT(080),PT(080),TS(080),RHO(080),FM(080),V(080),VX(080),     CD2       8
       3  VTH(080),Q(080),QP(080),BLKN(080),WC(080),WAKDEC(080),              CD2       9
       4  CB(080),ANGJ(080),DHOLES(080),ANHLES(080),FAM(080),CUMEA(080),      CD2      10
       5  VJET(080),ATCML(080),XR(080),CUMLE                                  CD2      11
        COMMON/CODMIT/IN,NOUT,IREAX,ITER,SMFF,SMFD                            CD2      12
        ICASE1=1                                                              MA        6
        ICASE2=1                                                              MA        7
        NELTOT=80                                                             MA        8
        IN=60                                                                 MA        9
        NOUT=61                                                               MA       10
        CALL PLOTS (0,0,0)                                                    MA       11
C ------     FIRST PASS,  REVERSE FLOW OR AXIAL FLOW O.D. ORIFICES  -----     MA       12
   70 IRUN=1                                                                  MA       13
        ICASE=ICASE1                                                          MA       14
        CALL COMANN                                                           MA       15
        ICASE1=ICASE                                                          MA       16
        IF (IREAX.EQ.0) GO TO 60                                              MA       17
        DP1=DP                                                                MA       18
        CDA1=CDOV*CUMGA                                                       MA       19
        LI=NELEM(1)                                                           MA       20
        WTOT=W(LI)                                                            MA       21
        IRUN=2                                                                MA       22
        ITER1=ITER                                                            MA       23
        CALL WTAPE(4)                                                         MA       24
C  ------     SECOND PASS  AXIAL FLOW I.D. ORIFICES  --------                 MA       25
        IRUN=1                                                                MA       26
        ICASE=ICASE2                                                          MA       27
        IF (ICASE.EQ.0) CALL RTAPE (7)                                        MA       28
        CALL COMANN                                                           MA       29
        ICASE2=ICASE                                                          MA       30
        DP2=DP                                                                MA       31
        CDA2=CDOV*CUMGA                                                       MA       32
        LI=NELEM(1)                                                           MA       33
        WTOT=WTOT+W(LI)                                                       MA       34
        IRUN=2                                                                MA       35
        ITER2=ITER                                                            MA       36
        IF (ITER1.NE.ITER2) GO TO 60                                          MA       37
C  ------     START ITERATION LOOP FOR AXIAL FLOW ANNULAR BURNERS  ----       MA       38
   25 WRITE (61,36) DP1,DP2,W1,W2,CDA1,CDA2                                   MA       39
   36 FORMAT (' ** FLOW ITERATION LOOP **'/' DP1 =',G10.3,                    MA       40
       1  5X,'DP2 =',G10.3,5X,'W1 =',G10.3,5X,'W2 =',G10.3/                   MA       41
       2  ' CDA1 =',G10.3,5X,'CDA2 =',G10.3)                                  MA       42
   26 IF (ABS(1.-DP1/DP2).LT..005) GO TO 50                                   MA       43
        IF (ITER.EQ.2) GO TO 50                                               MA       44
        DPAVG=.5*(DP1+DP2)                                                    MA       45
        W1=WTOT*CDA1/(CDA1+CDA2)                                              MA       46
        W2=WTOT-W1                                                            MA       47
        CALL WTAPE(7)                                                         MA       48
        CALL RTAPE(4)                                                         MA       49
        LI=NELEM(1)                                                           MA       50
        W(LI)=W1                                                              MA       51
        DP=DPAVG                                                              MA       52
        CALL COMANN                                                           MA       53
        CDA1=CDOV*CUMGA                                                       MA       54
        DP1=DP                                                                MA       55
        CALL WTAPE(4)                                                         MA       56
        CALL RTAPE(7)                                                         MA       57
        LI=NELEM(1)                                                           MA       58
        W(LI)=W2                                                              MA       59
        DP=DPAVG                                                              MA       60
        CALL COMANN                                                           MA       61
        CDA2=CDOV*CUMGA                                                       MA       62
        DP2=DP                                                                MA       63
        GO TO 25                                                              MA       64
C  ------      OUTPUT    ---------                                            MA       65
   50 CALL WTAPE(7)                                                           MA       66
        CALL RTAPE(4)                                                         MA       67
```

```
   80 CALL PROUT(NEL)                                              MA   68
      IF (IPIC.EQ.1) CALL PICT(0)                                  MA   69
      IF (IREAX.EQ.0) GO TO 70                                     MA   70
      CALL WTAPE(4)                                                MA   71
      CALL RTAPE(7)                                                MA   72
      CALL PROUT(NEL)                                              MA   73
      IF (IPIC.EQ.1) CALL PICT(0)                                  MA   74
      CALL WTAPE(7)                                                MA   75
      CALL RTAPE(4)                                                MA   76
      GO TO 70                                                     MA   77
C     ----------    ERROR MESSAGES  -----                          MA   78
   60 WRITE (NOUT,75) ITER1,ITER2                                  MA   79
   75 FORMAT (' **INCORRECT ITER SPECIFICATION, ITER1 = ',I5,      MA   80
     1 '    ,ITER2 = ',I5)                                         MA   81
      END                                                          MA   82
```

```
      SUBROUTINE TAPE(NT)                                               TA      2
      COMMON/CPICT/XNO,YNO,XFV,YFV,XOV,YOV,XBB(080),YBB(080),XG,YG,     CD1     2
     1  SIZE,XTI,YTI,XMOVE,YMOVE,DATA(12),PTYL(1,3)                    CD1     3
      COMMON/INPUTC/DP,BLKF,SK,RG,FRIC,TANS,CDS,NEL,TITLE(10),NELTOT,   CD2     2
     +  NELEM(080),NETYP(080),RO(080),XO(080),XI(080),CL(080),RI(080), CD2     3
     2  TLIN(080),BLKI(080),DBLK(080),WBPCT(080),NHOLES(080),NHTYP(080), CD2   4
     3  ISEP(080),IDBUG,NFW(080),IPIC,ABETA(080),SIGN,SIGN2,IRUN,ICASE CD2     5
      COMMON/OUTPUT/PTDIS,CDOV,WCORRI,CUMGA,CUMWJ,RR(080),W(080),       CD2     6
     1  AX(080),BLKW(080),BLKS(080),EAX(080),EAF(080),BETA(080),PS(080), CD2   7
     2  W(080),TT(080),PT(080),TS(080),RHO(080),EM(080),V(080),VX(080), CD2     8
     3  VTH(080),Q(080),OP(080),BLKM(080),WL(080),WAKDEC(080),          CD2     9
     4  CD(080),ANGJ(080),DHOLES(080),AHOLES(080),EAN(080),CUMEA(080),  CD2    10
     5  VJET(080),ATCHL(080),XB(080),CUMLF                              CD2    11
      COMMON/CODBIT/IN,NOUT,IREAX,ITER,SWFF,SWFD                        CD2    12
      ENTRY RTAPE                                                       TA      5
      REWIND NT                                                         TA      6
      READ (NT) XNO,YNO,XFV,YFV,XOV,YOV,XBB,YBB,XG,YG,SIZE,XTI,         TA      7
     1  YTI,XMOVE,YMOVE,DATA,PTYL                                       TA      8
      READ  (NT) DP,BLKF,SK,RG,FRIC,TANS,CDS,NEL,TITLE,NELTOT,NELEM,    TA      9
     1  NETYP,RO,XO,XI,CL,RI,TLIN,BLKI,DBLK,WBPCT,NHOLES,NHTYP,ISEP,    TA     10
     2  IDBUG,NFW,IPIC,ABETA,SIGN,SIGN2,IRUN,ICASE                      TA     11
      READ  (NT) PTDIS,CDOV,WCORRI,CUMGA,CUMWJ,RR,W,AX,BLKW,BLKS,EAX,   TA     12
     1  EAF,BETA,PS,W,TT,PT,TS,RHO,EM,V,VX,VTH,Q,OP,BLKM,WL,WAKDEC,     TA     13
     2  CD,ANGJ,DHOLES,AHOLES,EAN,CUMEA,VJET,ATCHL,XB,CUMLF             TA     14
      READ (NT) ITER,SWFF,SWFD                                          TA     15
      RETURN                                                            TA     16
C     -------------------------                                         TA     17
      ENTRY WTAPE                                                       TA     18
      REWIND NT                                                         TA     19
      WRITE (NT) XNO,YNO,XFV,YFV,XOV,YOV,XBB,YBB,XG,YG,SIZE,XTI,        TA     20
     1  YTI,XMOVE,YMOVE,DATA,PTYL                                       TA     21
      WRITE (NT) DP,BLKF,SK,RG,FRIC,TANS,CDS,NEL,TITLE,NELTOT,NELEM,    TA     22
     1  NETYP,RO,XO,XI,CL,RI,TLIN,BLKI,DBLK,WBPCT,NHOLES,NHTYP,ISEP,    TA     23
     2  IDBUG,NFW,IPIC,ABETA,SIGN,SIGN2,IRUN,ICASE                      TA     24
      WRITE (NT) PTDIS,CDOV,WCORRI,CUMGA,CUMWJ,RR,W,AX,BLKW,BLKS,EAX,   TA     25
     1  EAF,BETA,PS,W,TT,PT,TS,RHO,EM,V,VX,VTH,Q,OP,BLKM,WL,WAKDEC,     TA     26
     2  CD,ANGJ,DHOLES,AHOLES,EAN,CUMEA,VJET,ATCHL,XB,CUMLF             TA     27
      WRITE (NT) ITER,SWFF,SWFD                                         TA     28
      RETURN                                                            TA     29
      END                                                               TA     30
```

```
      SUBROUTINE C3RANN                                                 CO       2
      COMMON/CPICT/XNO,YNO,XFV,YFV,XOV,YOV,XBB(080),YBB(080),XG,YG,     CD1      2
     1  SIZE,XTI,YTI,XMOVE,YMOVE,DATA(12),PTYL(1,1)                     CD1      3
      COMMON/INPUTC/DP,BLKF,SK,RG,FRIC,TANS,CDM,NEL,TITLE(10),NELTOT,   CD2      2
     +  NELEN(080),NETYP(080),DD(080),XD(080),XI(080),CL(080),DI(080),  CD2      3
     2  TLIN(080),BLKI(080),BBLK(080),WBPCT(080),NHOLES(080),NHTYP(080),CD2      4
     3  ISEP(080),IDBUG,NFW(080),IPIC,ABETA(080),SIGM,SIGM2,IRUN,ICASE  CD2      5
      COMMON/OUTPUT/PTDIS,CDOV,NCONT,CUMGA,CUMWJ,RA(080),M(080),        CD2      6
     1  AX(080),BLKM(080),BLKS(080),EAX(080),EAF(080),BETA(080),PS(080),CD2      7
     2  W(080),TT(080),PT(080),TS(080),RHO(080),EM(080),V(080),VX(080), CD2      8
     3  VTH(080),Q(080),GP(080),BLKR(080),V (080),WAXDEC(080),          CD2      9
     4  CD(080),ANGJ(080),DNOLES(080),ANGLES(080),EAM(080),CUMEA(080),  CD2     10
     5  VJET(080),ATCML(080),XM(080),CUMLF                              CD2     11
      COMMON/CONBIT/IN,NOUT,IREAK,ITER,SWFF,SWFD                        CD2     12
   10 ICAS=ICASE                                                        CO       5
      IF (IRUN.GE.2) GO TO 15                                           CO       6
      IF (ICASE.EQ.1) CALL ZERO                                         CO       7
      ICASE=ICAS                                                        CO       8
C -------  READ INPUT DATA AND COMPUTE INLET CONDITIONS --------         CO       9
      CALL INPUT                                                        CO      10
   15 CALL INLET                                                        CO      11
C -------  INITIALIZE OVERALL ITERATION VARIABLES  ------               CO      12
      LI=NELEN(1)                                                       CO      13
      RTP=SQRT(TT(LI)/518.7)/(PT(LI)/14.7)                              CO      14
      NIT=0                                                             CO      15
      NITMAX=20                                                         CO      16
C  *************   START OF MAIN ITERATION LOOP  ***********            CO      17
   20 L=2                                                               CO      18
      NIT=NIT+1                                                         CO      19
      WRITE(61,4000) NIT                                                CO      20
 4000 FORMAT(/1X,*START ITERATION NO. *,I2)                             CO      21
C ------ CALC P-DISCHARGE FROM ESTIMATED DP  -------                    CO      22
      PTDIS=PT(LI)*(1.-DP)                                              CO      23
C -------   INITIALIZE LOOP ITERATION VARIABLES  -------                CO      24
      SWFF=0.                                                           CO      25
      SWFD=0.                                                           CO      26
      CUMLF=0.                                                          CO      27
      CUMGA=0.                                                          CO      28
      CUMWJ=0.                                                          CO      29
      CDOV=0.                                                           CO      30
      RELAX=1.0-.006*AMAX1(FLOAT(NEL-20),0.)                            CO      31
C -------   LOOP OVER ALL ELEMENTS  -------                             CO      32
   30 LL=NELEN(L)                                                       CO      33
      IF (NETYP(LL).EQ.INL.AND.NFW(LL).EQ.1)GO TO 40                    CO      34
      IF (NETYP(LL).EQ.INL)CALL LENGTH(L)                               CO      35
      IF (NETYP(LL).EQ.INF)CALL FLOW(L)                                 CO      36
      IF (IDBUG.EQ.2)CALL PROUT(L)                                      CO      37
      IF (EM(LL).LT.1.0) GO TO 40                                       CO      38
      GO TO (210,310), ITER                                             CO      39
   40 IF (L.EQ.NEL)GO TO 50                                             CO      40
      L=L+1                                                             CO      41
      GO TO 30                                                          CO      42
C --------- ERROR TEST ---------                                        CO      43
   50 WERR=CUMWJ-W(LI)                                                  CO      44
      IF (ABS(WERR)/W(LI).LT..0005) GO TO 80                            CO      45
      GO TO (200,300), ITER                                             CO      46
C --------- ITERATE FOR DP/P ---------                                  CO      47
  200 DP=DP*(1.-RELAX*WERR/CUMWJ)                                       CO      48
      WRITE (NOUT,90)  CUMWJ,WERR,DP                                    CO      49
      GO TO 410                                                         CO      50
  210 DP=DP*2.                                                          CO      51
      WRITE (NOUT,90) CUMWJ,WERR,DP                                     CO      52
      GO TO 410                                                         CO      53
C --------- ITERATE FOR INLET FLOW ---------                            CO      54
  300 IF (SWFF+SWFD.EQ.1.0) GO TO 304                                   CO      55
      W(LI)=W(LI)*(1.+RELAX*(SWFD/(1.-SWFF)-1.))                        CO      56
  304 WRITE (NOUT,100) CUMWJ,WERR,W(LI),SWFF,SWFD                       CO      57
      GO TO 400                                                         CO      58
  310 W(LI)=W(LI)/2.                                                    CO      59
      WRITE (NOUT,100) CUMWJ,WERR,W(LI),SWFF,SWFD                       CO      60
  400 CALL INLET                                                        CO      61
  410 IF (NIT.LT.NITMAX) GO TO 20                                       CO      62
      WRITE (NOUT,3000)   NIT                                           CO      63
C -----    EXIT PATH AFTER CONVERGENCE   -----------                    CO      64
   80 IF (CUMGA.EQ.0.) GO TO 85                                         CO      65
      CDOV=1.0106*CUMLF*RTP/(CUMGA*SQRT(DP))                            CO      66
   85 CONTINUE                                                          CO      67
```

```
      SUBROUTINE CONANN     73/74    OPT=0 TRACE                FTN 4.6+439        08/24/78  39.58.39        PAGE    2

          3000 FORMAT(* FLOW ITERATION DID NOT CONVERGE IN *,I2,* ITERATIONS*,/   CO      68
               *10X,*1. CHECK LENGTH ELEMENTS FOR BAD DIMENSIONS.    */           CO      69
  80           *10X,*2. CHECK FLOW ELEMENTS FOR ERRORS IN HOLE DIA, FLOW FRACTION, CO      70
               * OR NUMBER OF HOLES. */                                           CO      71
               *10X,*3. CHECK ORIFICE DISC4 COEFFICIENTS. CHANGE FIXED CD TYPES TO CO      72
               * FLOATING CD TYPES.*/                                             CO      73
               *10X,*4. INLET SWIRL ANGLE MAY BE TOO HIGH*/                       CO      74
  85           *10X,*5. CHECK FOR NEGATIVE PRESS. DROP ON FLOW ELEMENTS. MAY BE IN CO      75
               *PUT ERROR OR ANNULUS WIDTH TOO NARROW. *)                         CO      76
                IF(ITER.EQ.1.AND.NIT.LT.NITMAX) WRITE(NOUT,110) CONWJ,WERR,DP     CO      77
                IF(ITER.EQ.2.AND.NIT.LT.NITMAX) WRITE(NOUT,120) CONWJ,WERR        CO      78
                RETURN                                                            CO      79
  90      C                                                                       CO      80
            90 FORMAT (17H TOTAL JET FLOW= ,F8.4,13H FLOW ERROR= ,F9.6,20H NEW PR CO      81
               *ESSURE DROP= ,F9.6/)                                              CO      82
           100 FORMAT (10H TOTAL JET FLOW = ,F9.6,14H FLOW ERROR = ,F9.6,         CO      83
              1  17H NEW FLOW RATE = ,F9.6,13H SUFF,SUFD = ,2F9.4)                CO      84
  95       110 FORMAT (37H SOLUTION CONVERGED, TOTAL JET FLOW= ,F8.4, 13H FLOW ER CO      85
               *ROR= ,F9.6, 22H FINAL PRESSURE DROP= ,F9.6/)                      CO      86
           120 FORMAT (37H SOLUTION CONVERGED, TOTAL JET FLOW= ,F8.4, 13H FLOW ER CO      87
               *ROR= ,F9.6/)                                                      CO      88
          C     END CONANN                                                        CO      89
  100           END                                                               CO      90

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

   89      I                  AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   96      I                  AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
```

```
SUBROUTINE ZERO        73/74    OPT=0 TRACE                    FTN 4.6+439         08/24/78  09.50.30        PAGE     1

  1                 SUBROUTINE ZERO                                                           ZE
                    COMMON/CPICT/XMO,YMO,XFV,YFV,X9V,Y9V,XBB(000),YBB(000),XG,YG,             C01
                   1  SIZE,XTI,YTI,XMOVE,YMOVE,DATA(12),PXYL(1,1)                             C01
                    COMMON/INPUT/BP,[illegible],TITLE(10),NELTOT,                             C02
  5                +  NELEM(000),METYP(000),[illegible]                                       C02
                   2  [illegible]                                                             C02
                   3  ISEF(000),IDBUG,[illegible],ICASE                                       C02
                    COMMON/OUTPUT/PTBIS,[illegible]                                           C02
                   1  AX(000),[illegible],BETA(000),PS(000),                                  C02
 10                2  [illegible],V(000),VX(000),                                             C02
                   3  [illegible]                                                             C02
                   4  CB(000),[illegible],CUMEA(000),                                         C02
                   5  VJET(000),[illegible],CUMLF                                             C02
                    COMMON/CONMIT/IN,NOUT,[illegible],SUFF,SUF9                               C02
 15                 CALL MEMSET (XMO,PXYL(1,1))                                               ZE
                    CALL MEMSET (BP,ICASE,0.0)                                                ZE
                    CALL MEMSET (PTBIS,CUMLF,0.0)                                             ZE
              C     END ZERO                                                                  ZE
                    END                                                                       ZE

CARD NO. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

     15      I        3         ARGUMENT COUNT INCONSISTENT WITH PRIOR USAGE.
     17      I        3         ARGUMENT COUNT INCONSISTENT WITH PRIOR USAGE.
```

```
      SUBROUTINE INPUT                                                  IN     2
      COMMON/CPICT/XMB,YMB,XFV,YFV,XDV,YDV,XBB(080),YBB(080),XG,YG,     CD1    2
     1  SIZE,XTI,YTI,XMOVE,YMOVE,DATA(12),PKYL(1,1)                     CD1    3
      COMMON/INPUTC/DP,BLKF,SK,RS,FRIC,TANS,CDO,NEL,TITLE(10),NELTOT,   CD2    2
     + NELEM(080),NETYP(080),RO(080),XO(080),XI(080),CL(080),RI(080),   CD2    3
     2  TLIM(080),BLKI(080),DBLK(080),WBPCT(080),NHOLES(080),NHTYP(080), CD2   4
     3  ISEP(080),IDBUG,NFW(080),IPIC,ABETA(080),SIGN,SIGN2,IRUN,ICASE  CD2    5
      COMMON/OUTPUT/PTDIS,CDOW,NCDMRI,CUMGA,CUMWJ,RR(080),H(080),       CD2    6
     1  AX(080),BLKW(080),BLKS(080),EAX(080),EAF(080),BETA(080),PS(080), CD2   7
     2  W(080),TT(080),PT(080),TS(080),PHO(080),EM(080),V(080),VX(080), CD2    8
     3  VTM(080),Q(080),QP(080),BLKM(080),W (080),WAKDEC(080),          CD2    9
     4  CD(080),ANGJ(080),DHOLES(080),ANOLES(080),EAM(080),CUMEA(080),  CD2   10
     5  VJET(080),ATCHL(080),FB(080),CUMLF                              CD2   11
      COMMON/COBBIT/IN,NOUT,IREAK,ITEP,SUFF,SUFG                        CD2   12
      ITEP=0                                                            IN     5
      IBAD=0                                                            IN     6
      IF (ICASE.EQ.1)II=0                                               IN     7
      READ (60,120)TITLE,ITER,IPIC,IDBUG                                IN     8
      IF (EOF(60))110,10                                                IN     9
   10 READ (60,130)NTYP,NFMT,NELM,NELI,(DATA(J),J=1,8)                  IN    10
      IF(NELM.EQ.0.AND.NTYP.NE.1H..AND.NTYP.NE.1H ) IBAD=1+IBAD         IN    11
      IF(NELM.EQ.0.AND.NTYP.NE.1H..AND.NTYP.NE.1H ) NELM=NELTOT-IBAD    IN    12
      IF (NTYP.EQ.1HI)ICARD=1                                           IN    13
      IF (NTYP.EQ.1HF)ICARD=2                                           IN    14
      IF (NTYP.EQ.1HL)ICARD=3                                           IN    15
      IF (NTYP.EQ.1H.)ICARD=4                                           IN    16
      IF (NTYP.EQ.1H )ICARD=4                                           IN    17
      IF (NTYP.EQ.1HP)ICARD=5                                           IN    18
      IF (NTYP.EQ.1HB)ICARD=6                                           IN    19
      IF (NTYP.EQ.1HC)ICARD=7                                           IN    20
      ICKCGT=ICARD                                                      IN    21
      IF (ICKCGT.LE.1)GO TO 20                                          IN    22
      IF (ICKCGT.GE.7)GO TO 100                                         IN    23
      GO TO (20,30,50,60,70,90,100),ICKCGT                              IN    24
   20 I=NELI                                                            IN    25
      W(I)=DATA(1)                                                      IN    26
      PT(I)=DATA(2)                                                     IN    27
      TT(I)=DATA(3)                                                     IN    28
      BETA(I)=DATA(4)                                                   IN    29
      IF (NFMT.EQ.1HO)GO TO 15                                          IN    30
      DP=DATA(5)                                                        IN    31
      NEL=NELM                                                          IN    32
      GO TO 10                                                          IN    33
   30 IF (ICASE.EQ.1)II=II+1                                            IN    34
      IF (ICASE.EQ.1)NELEM(II)=NELM                                     IN    35
      I=NELM                                                            IN    36
      IM=NELEM(II-1)                                                    IN    37
      RO(I)=RO(IM)                                                      IN    38
      RI(I)=RI(IM)                                                      IN    39
      XO(I)=XO(IM)                                                      IN    40
      XI(I)=XI(IM)                                                      IN    41
      NETYP(I)=NTYP                                                     IN    42
      NFW(I)=NFMT                                                       IN    43
      WBPCT(I)=DATA(1)                                                  IN    44
      BLKI(I)=1.0                                                       IN    45
      DBLK(I)=1.0                                                       IN    46
      CL(I)=0.                                                          IN    47
      IF (NFMT.EQ.1HI)GO TO 40                                          IN    48
      NHOLES(I)=DATA(2)                                                 IN    49
      NHTYP(I)=DATA(3)                                                  IN    50
      CD(I)=DATA(4)                                                     IN    51
      DHOLES(I)=DATA(5)                                                 IN    52
      ISEP(I)=DATA(6)                                                   IN    53
      VJET(I)=0.                                                        IN    54
      ANGJ(I)=0.                                                        IN    55
      ABETA(I)=0.                                                       IN    56
      GO TO 10                                                          IN    57
   40 VJET(I)=DATA(2)                                                   IN    58
      ANGJ(I)=DATA(3)                                                   IN    59
      ABETA(I)=DATA(4)                                                  IN    60
      NHOLES(I)=0.                                                      IN    61
      NHTYP(I)=0.                                                       IN    62
      CD(I)=0.                                                          IN    63
      DHOLES(I)=0.                                                      IN    64
      ISEP(I)=0                                                         IN    65
      GO TO 10                                                          IN    66
   50 IF (ICASE.EQ.1)II=II+1                                            IN    67
```

```
      IF (ICASE.EQ.1)NELEN(II)=NELM
      I=NELN
      NFTYP(I)=NTYP
      NFV(I)=NFUT
      XO(I)=DATA(1)
      RC(I)=DATA(2)
      XI(I)=DATA(3)
      RI(I)=DATA(4)
      CL(I)=DATA(5)
      TLIM(I)=DATA(6)
      LI=NELEN(I)
      IF (TLIM(I).EQ.0..AND.NFUT.EQ.1H )TLIM(I)=TT(LI)
      BLKI(I)=DATA(7)
      IF (BLKI(I).EQ.0.)BLKI(I)=1.0
      BBLK(I)=DATA(8)
      IF (BBLK(I).EQ.0.)BBLK(I)=1.0
      GO TO 10
   60 CALL PINPUT
      IF (ICASE.EQ.1.AND.II.NE.NEL)WRITE (51,140)II,NEL
      IF (ICASE.EQ.1.AND.II.LT.NEL)NEL=II
      IF (NFUT.EQ.1H )ICASE=0
      IF (NFUT.EQ.1H.)ICASE=1
      RETURN
   70 NCARDS=DATA(1)
      IF (1.GT.NCARDS)GO TO 5
      DO 80 J=1,NCARDS
   80 READ (60,150)(FXVL(J,M),M=1,12)
    5 CONTINUE
      GO TO 10
   90 NCARDS=DATA(1)
      READ (60,160)XNO,YNO,XFV,YFV,XOV,YOV,XG,YG,SIZE,XTI,YTI,XMOVE,YMOV
     +E
      IF (1.GT.NCARDS) GO TO 6
      DO 95 J=1,NCARDS
      READ (60,170)X1,Y1,N1,X2,Y2,N2,X3,Y3,N3,X4,Y4,N4
      XBB(N1)=X1
      XBB(N2)=X2
      XBB(N3)=X3
      XBB(N4)=X4
      YBB(N1)=Y1
      YBB(N2)=Y2
      YBB(N3)=Y3
      YBB(N4)=Y4
   95 YBB(N4)=Y4
    6 CONTINUE
      GO TO 10
  100 FRIC=DATA(1)
      BLFF=DATA(2)
      TANS=DATA(3)
      CDB=DATA(4)
      SK=DATA(5)
      RG=DATA(6)
      IREAX=IFIX(DATA(7))
      GO TO 10
  110 CALL PLOT(0,0,3)
      CALL PLOT(0,0,999)
      CALL EXIT
C
  120 FORMAT (9A8,A5,3I1)
  130 FORMAT (A1,A1,I3,I3,2X,6F10.3,2F5.0)
  140 FORMAT (5X,33HNOTE - NUMBER OF ELEMENTS INPUT, ,I3,39H NOT EQUAL N
     +UMBER SPECIFIED ON I CARD (,I3,1H))
  152 FORMAT (12F6.5)
  150 FORMAT (13F6.0)
  170 FORMAT (4(2F6.0,I3,3X))
      RETURN
C     END INPUT
      END
```

CARD NR. SEVERITY DETAILS   DIAGNOSIS OF PROBLEM

140   I   20CD 140   FIELD WIDTH OF A CONVERSION DESCRIPTOR SHOULD BE AS LARGE AS THE MINIMUM SPECIFIED FOR THAT DESCRIPTOR.

SUBROUTINE PINPUT   73/74   OPT=0 TRACE   FTN 4.6+439   08/24/78 09.58.39   PAGE   1

```
      SUBROUTINE PINPUT
      COMMON/INPUTC/DP,BLKF,SK,RS,FRIC,TANS,CDS,NEL,TITLE(10),NELTOT,
     + NELEM(080),NETYP(080),RO(080),XO(080),ZI(080),CL(080),RI(080),
     2 TLIN(080),BLEI(080),BLK(080),WSPCT(080),NHOLES(080),NHTYP(080),
     3 ISEP(080),IDBUG,NFW(080),IPIC,ABETA(080),SIGM,SIGM2,IRUN,ICASE
      COMMON/OUTPUT/PTDIS,CDOV,WCOPT,COMGA,COMWJ,RB(080),H(080),
     1 X(080),BLKJ(080),BLK*(080),FAX(080),EAF(080),BETA(080),PS(080),
     2 W(080),TT(080),PT(080),TS(080),PHO(080),EM(080),V(080),VX(080),
     3 VIN(080),Q(080),DP(080),RLEN(080),WL(080),MAXREC(080),
     4 CD(080),ANGJ(080),DHOLES(080),ANGLE(080),EAP(080),CAREA(080),
     5 VJET(080),ATCHL(080),TS(080),CONLF
      COMMON/CODBIT/IN,NOUT,IREAD,ITER,SUFF,SUFO
      WRITE (61,20) TITLE
      IF (ITER.EQ.1)WRITE (61,40)
      IF (ITER.EQ.2)WRITE (61,50)
      IF (IPIC.EQ.0)WRITE (61,60)
      IF (IPIC.EQ.1)WRITE (61,70)
      IF (IDBUG.EQ.0)WRITE (61,80)
      IF (IDBUG.EQ.1)WRITE (61,90)
      IF (IDBUG.EQ.2)WRITE (61,100)
      WRITE (61,110)DP,BLKF,SK,RS,FRIC,TANS,CDS,NEL
      WRITE (61,120)
      IF (1.GT.NEL)GO TO 5
      DO 10 LL=1,NEL
      L=NELEM(LL)
      IF (NETYP(L).EQ.1HL)WRITE (61,130)NELEM(LL),NETYP(L),NFW(L),XO(L),
     +RO(L),XI(L),RI(L),CL(L),TLIN(L),BLEI(L),BLK(L)
      IF (NETYP(L).EQ.1HF)WRITE (61,140)NELEM(LL),NETYP(L),NFW(L),DHOLES
     +(L),NHOLES(L),NHTYP(L),CD(L),WSPCT(L)
   10 CONTINUE
    5 CONTINUE
      RETURN
C
   20 FORMAT (1H1,10A8//8X,13HINPUT DATA - )
   40 FORMAT (10X,95HCALCULATION CONTROLS - SOME (OR ALL) HOLES FIXED SI
     +ZE, ITERATE TO FIND PRESSURE DROP (ITER = 1))
   50 FORMAT (10X,110HCALCULATION CONTROLS - PRESSURE DROP FIXED - SOME
     +HOLES FIXED SIZE, SIZE VARIABLE HOLES BY ADJUSTING FLOW (ITER = 2)
     +)
   60 FORMAT (33X,38HPICTURE WILL NOT BE PLOTTED (IPIC = 0))
   70 FORMAT (33X,34HPICTURE WILL BE PLOTTED (IPIC = 1))
   80 FORMAT (33X,60HOUTPUT PRINTING OCCURS AFTER FINAL SOLUTION ONLY (I
     +DBUG = 0))
   90 FORMAT (33X,60HOUTPUT PRINTING OCCURS AFTER EACH FLOW ITERATION (I
     +DBUG = 1))
  100 FORMAT (33X,53HOUTPUT PRINTING OCCURS AFTER EACH ELEMENT (IDBUG =
     +2))
  110 FORMAT (10X,24HOVERALL PRESSURE DROP - ,F6.4/10X,32HANNULUS EFFECT
     +IVE AREA FACTOR - ,F6.4/10X,30HAIR RATIO OF SPECIFIC HEATS - ,F7.3
     +/10X,19HAIR GAS CONSTANT - ,F6.3/10X,32HANNULUS WALL ROUGHNESS FAC
     +TOR - ,F7.4/10X,37HTANGENT OF SEPARATION SPREAD ANGLE - ,F7.4/10X,
     +41HDRAG COEFFICIENT FOR INSERTED BLOCKAGE - ,F8.4/10X,30HNUMBER OF
     + POSITION ELEMENTS - ,I3/)
  120 FORMAT (12X,35HDIMEN. AT DOWNSTREAM END OF ELEMENT,/12X,1H-,1H-,1H
     +-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,
     +1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,/1
     +2X,40H  XO          RO          XI          RI          CL          WALL,4X,59HINSE
     +RT   INSERT      HOLE        NUMBER   HOLE   DISCH ORIFICE,/1X,61HELEM  E
     +LEM   OUTER     OUTER       INNER       INNER     ELEMENT   TEMP,,3X,24H AREA
     +     DIAMETER    DIAM        OF        TYPE   COEFF FLOW /,/1X,58H NO.   TYP
     +E   LENGTH    RADIUS      LENGTH    RADIUS    LENGTH      0:6X,55HFACTOR
     +IN.         IN.         HOLES                 FLOW IN,/1X,1H-,1H-,1H-,1H-,
     +1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H
     +-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,
     +1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H
     +-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,
     +1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H
     +-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,
     +1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H-,1H
     +-,//)
  130 FORMAT (2X,I3,3X,A1,A1,2X,F7.3,2X,F7.3,2X,F7.3,2X,F7.3,2X,F7.3,2X,
     +F6.1,2X,F6.3,2X,F7.3)
  140 FORMAT (2X,I3,3X,A1,A1,73X,F5.4,1X,I5,3X,I4,2X,F6.4,1X,F7.4)
C     END PINPUT
      END
```

SUBROUTINE INLET 73/74 OPT=0 TRACE FTN 4.6+439 08/24/78 09.58.30 PAGE 1

```
      SUBROUTINE INLET
      COMMON/INPUT/[illegible],BLKF,SK,RS,FRIC,TANS,COS,NEL,TITLE(10),NELTOT,
     + NELEM(050),NETYP(050),RO(050),XO(050),TI(050),CL(050),RI(050),
     1 TITLE(050),BLKI(050),BLK(050),[illegible],[illegible]ES(050),[illegible](050),
     2 [illegible](050),[illegible],STEP,[illegible],ICASE
     3 [illegible]
      COMMON/OUTPUT/[illegible],PS(050),
     1 AX(050),[illegible],BLKS(050),EAX(050),EAF(050),BETA(050),VX(050),
     2 VC(050),TT(050),PT(050),TS(050),[illegible],WAKDEC(050),
     3 VTH(050),[illegible],OP(050),BLKM(050),W(050),[illegible],
     4 CU(050),ANG(050),ANGLES(050),ANGLES(050),CAN(050),CUREA(050),
     5 [illegible],ATCHL(050),ZO(050),[illegible]
      COMMON/CONST/[illegible],IREAF,ITER,SUFF,SUFB
      I=1
      L=NELEM(1)
      WCORR=W(L)*SQRT(TT(L)/518.7)/(PT(L)/14.7)
   10 CALL XAREA(RO(L),RI(L),XO(L),XI(L),RB(L),[illegible](L),AX(L),XB(L))
      CUREA(L)=0.
      ATCHL(L)=0.
      EAX(L)=AX(L)*BLKF*BLKI(L)
      RBETA=BETA(L)/57.296
      EAF(L)=EAX(L)*COS(RBETA)
      IMACH=0
      CALL MACH(IMACH,W(L),PT(L),TT(L),EAF(L),RBETA,SK,RS,EM(L),TS(L),PS
     +(L),[illegible](L),V(L),VX(L),VTH(L),[illegible](L),WP(L))
      BLKS(L)=1.0
      BLKS(L)=1.0
      BLKM(L)=BLKI(L)
      W(L)=0.
      IF (I.EQ.2)RETURN
      L=NELEM(2)
      IF (NETYP(L).NE.INL.OR.[illegible](L).NE.[illegible])RETURN
      I=2
      GO TO 10
C     END INLET
      END
```

```
      SUBROUTINE LENGTH(LL)
      COMMON/INPUTC/DP,BLKF,SK,RG,FRIC,TANS,CDO,NEL,TITLE(10),NELTOT,
     + NELEM(080),METYP(080),RB(080),XD(080),XI(080),CL(080),PI(080),
     2 TLIN(080),BLKI(080),BLKI(080),WBPCT(080),ANGLES(080),ANTYP(080),
     3 ISEP(080),IDBUG,NFW(080),IPIC,ABETA(080),SIGN,SIGN2,INDW,ICASE
      COMMON/OUTPUT/PTDIS,CBOW,WCBMRT,CONGE,CONWJ,RB(080),H(080),
     1 AX(080),BLKW(080),BLKS(080),EAX(080),EAF(080),BETA(080),PS(080),
     2 W(080),TT(080),PT(080),TS(080),RHO(080),EM(080),V(080),VX(080),
     3 VTH(080),O(080),OP(080),BLKM(080),W(080),ZANDEC(080),
     4 CB(080),ANGJ(300),ONGLES(080),ANGLES(080),EAN(080),CONEA(080),
     5 VJET(080),ATCHL(080),XB(080),CONLF
      COMMON/CODBIT/IN,NOUT,IREAT,ITEP,SNFF,SNFD
      II=LL-1
      L=NELEM(LL)
      I=NELEM(II)
      CONEA(L)=0.
      W(L)=W(I)
      EMB=EM(I)*EM(I)
      EAN(L)=0.
      NIT=0
      PBETAI=BETA(I)/57.296
      CALL XAREA(PD(L),XI(L),XD(L),XI(L),RB(L),H(L),AX(L),XB(L))
      IF (CL(L).EQ.0.)CL(L)=SQRT((ABS(XB(L)-XB(I)))**2.+(ABS(RB(L)-RB(I
     +))**2.)
      CALL DELTO(TT(I),V(I),RHO(I),H(I),PT(I),CL(L),W(I),TLIN(L),TT(L),D
     +TT,FRIC,FF,NFW(L))
      THFR=FF*CL(L)/H(I)*TAN(RBETAI)
      IF (THFR.LT.0.)THFR=0.
      THFK=(1.+THFR)
      CALL WAKE(I,L,II)
      BLKS(L)=BLKS(I)*AX(I)/AX(L)**B(L)/RB(I)+TANS*CL(L)/H(L)/COS(RBETAI
     +)
      ATCHL(L)=0.
      IF (BLKS(L).LE.1.)GO TO 10
      BLKS(L)=1.0
      ATCHL(L)=COS(RBETAI)*(H(L)-BLKS(I)*H(I))/TANS
      IF (ATCHL(L).LT.0.)ATCHL(L)=0.
   10 EAX(L)=BLKS(L)*BLKW(L)*BLKI(L)*BLKF*AX(L)
      VX(L)=VX(I)*EAX(I)/EAX(L)
      VTH(L)=VTH(I)*RB(I)/RB(L)/THFK
      V(L)=SQRT(VX(L)**2+VTH(L)**2)
      RHO(L)=RHO(I)
   20 RBETAL=ATAN(VTH(L)/VX(L))
      EAF(L)=EAX(L)*COS(RBETAL)
      DAA=ALOG(EAF(L)/EAF(I))
      DF=2.*FF*CL(L)/COS(RBETAL)/H(L)*CDO*(1.-BLKI(I))
      DWW=0.
      Y=1
      CALL AKR(DAA,DTT,DF,DWW,Y,SK,EM(I),EMB,EM(L))
      IF (EM(L).GE.1.)RETURN
      EMB=(EM(I)*EM(I)+EM(L)*EM(L))/2.
      PAK=-SK*EMB/2.*(DTT+DF)
      PT(L)=PT(I)*EXP(PAK)
      CALL MAC4(1,W(L),PT(L),TT(L),EAF(L),RBETAL,SK,RG,EM(L),TS(L),PS(L)
     +,RHO(L),V(L),VX(L),VTHW,O(L),OP(L))
      NIT=NIT+1
      BETACK=RBETAL*57.2957795
      BETA(L)=57.2957795*ATAN(VTH(L)/VX(L))
      IF (NIT.EQ.1)GO TO 20
      IF (NIT.EQ.10)GO TO 30
      IF (ABS(BETA(L)-BETACK).GT..05)GO TO 20
   30 RETURN
C     END LENGTH
      END
```

```
      SUBROUTINE WAKE(I,L,II)                                          WA     2
      COMMON/INPUTC/DP,BLKF,SK,RG,FRIC,TANS,CDB,NEL,TITLE(10),NELTOT,  CD2    2
     * NELEM(000),METYP(000),DD(000),XO(000),XI(050),CL(000),PI(000),  CD2    3
     2 TLINE(000),BLKI(000),BBLK(000),DBPCT(000),NHOLES(000),NHTYP(050),CD2   4
     3 ISEP(000),[illegible],[illegible](000),IPIC,ABETA(000),STCH,STCH2,ICBN,ICASE CD2 5
      COMMON/OUTPUT/PTDIS,[illegible],[illegible],CUMGA,CUMWJ,RB(000),H(000), CD2 6
     1 AX(000),BLFU(000),BLKS(000),EAX(000),FAF(000),BETA(000),PS(000),CD2    7
     2 W(000),TT(000),PT(000),TS(000),RHO(000),EP(000),V(000),VX(000), CD2    8
     3 VIN(000),A(000),DP(000),BLKM(000),WL(000),WAKDEC(000),          CD2    9
     4 CD(000),ANGI(000),ANGLES(000),ANGLES(000),EAN(000),CUMEA(000),  CD2   10
     5 VJET(000),ATCHL(000),RB(000),CUMLP                              CD2   11
      COMMON/CODBIT/IN,MOUT,IREAT,ITER,SUFF,SWFD                       CD2   12
      WL(I)=0.                                                         WA     4
      WAKDEC(I)=(1.-BLKI(I))/(5.*BBLK(I))                              WA     5
      WLI=CL(L)/COS(BETA(I)/57.296)                                    WA     6
      BLKW(L)=1.0                                                      WA     7
      IF (I.GT.II)GO TO 5                                              WA     8
      DO 20 MM=1,II                                                    WA     9
      M=NELEM(MM)                                                      WA    10
      WL(M)=WL(M)+WLI                                                  WA    11
      IF (MM.EQ.II)GO TO 10                                            WA    12
      IF (BLKM(M).EQ.1.)GO TO 20                                       WA    13
   10 BLKM(M)=WAKDEC(M)*WL(M)+BLKI(M)                                  WA    14
      IF (BLKM(M).GT.1.)BLKM(M)=1.0                                    WA    15
   20 BLKW(L)=BLKW(L)*BLKM(M)                                          WA    16
    5 CONTINUE                                                         WA    17
      RETURN                                                           WA    18
C     END WAKE                                                         WA    19
      END                                                              WA    20
```

```
      SUBROUTINE FLOW(LL)                                                FL     2
      COMMON/INPUT/DP,BLKF,SK,RE,FRIC,TAMS,CDB,NEL,TITLE(10),NELTOT,     CB2    2
     * NELEM(080),KETYP(G30),RO(090),XO(300),XI(080),CL(080),PI(080),    CB2    3
     2 TLIN(080),BLKI(080),BMLK(080),WBPCT(080),MANGLES(080),NATYP(080), CB2    4
     3 ISEP(080),JBDUG,NFW(080),IPIC,AREFA(080),SIGM,SIGM2,IRUN,ICASE    CB2    5
      COMMON/OUTPUT/PTDIS,CDDY,NCOMPT,CUMGA,CUMGJ,RB(080),M(080),        CB2    6
     1 AX(080),BLKW(080),BLKS(080),EAX(080),EAF(080),BETA(080),PS(080),  CB2    7
     2 W(080),TT(080),PT(080),TS(080),RHO(080),EM(080),V(080),VX(080),   CB2    8
     3 VTH(080),Q(080),QP(080),BLCH(080),WL(080),WAKDEC(080),            CB2    9
     4 CB(080),ANGJ(080),SMBLES(080),AMBLES(080),CAM(080),CUMEA(080),    CB2   10
     5 VJET(080),ATCHL(080),X9(080),CUMLF                                CB2   11
      COMMON/CODBIT/IN,NBUT,IREAX,ITER,SWFF,SWFD                         CB2   12
      II=LL-1                                                            FL     4
      L=NELEM(LL)                                                        FL     5
      I=NELEM(II)                                                        FL     6
      NIT=0                                                              FL     7
      Y=1                                                                FL     8
      ATCHL(L)=0.                                                        FL     9
      PT(L)=PT(I)                                                        FL    10
      TT(L)=TT(I)                                                        FL    11
      RO(L)=RO(I)                                                        FL    12
      RI(L)=RI(I)                                                        FL    13
      XO(L)=XO(I)                                                        FL    14
      XI(L)=XI(I)                                                        FL    15
      AX(L)=AX(I)                                                        FL    16
      RB(L)=RB(I)                                                        FL    17
      XB(L)=XB(I)                                                        FL    18
      W(L)=W(I)                                                          FL    19
      TLIN(L)=TLIN(I)                                                    FL    20
      CL(L)=0.                                                           FL    21
      CALL WAKE(I,L,II)                                                  FL    22
      BLKS(L)=BLKS(I)                                                    FL    23
      IF (ISEP(L).EQ.1)BLKS(L)=1.0                                       FL    24
      EMB=EM(I)*EM(I)                                                    FL    25
      EAX(L)=BLKS(L)*BLKW(L)*BLKF*AX(L)                                  FL    26
      IF (NFW(L).EQ.1MI)GO TO 10                                         FL    27
      CALL JET(I,L,LL,WJW)                                               FL    28
      VTH(L)=VTH(I)                                                      FL    29
      GO TO 20                                                           FL    30
   10 CALL MIX(I,L,WJW,Y)                                                FL    31
   20 WP=1.-WJW                                                          FL    32
      IF (WR.LE.0. .AND. LL.LT.NEL) WP=1.0                               FL    33
      IF (WR.LE.0. .AND. LL.GE.NEL) WR=.01                               FL    34
      W(L)=W(I)*WR                                                       FL    35
      VX(L)=VX(I)*WP                                                     FL    36
   30 RBETAL=ATAN(VTH(L)/VX(L))                                          FL    37
      BETACH=RBETAL*57.2957795                                           FL    38
      EAF(L)=EAX(L)*COS(RBETAL)                                          FL    39
      DAA=ALOG(EAF(L)/EAF(I))                                            FL    40
      DWW=ALOG(W(L)/W(I))                                                FL    41
      DTT=ALOG(TT(L)/TT(I))                                              FL    42
      DF=0.                                                              FL    43
      CALL AMF(DAA,DTT,DF,DWW,Y,SK,EM(I),EMB,EM(L))                      FL    44
      IF (EM(L).GE.1.)RETURN                                             FL    45
      EMB=(EM(I)*EM(I)+EM(L)*EM(L))/2.                                   FL    46
      PAK=-SK*EMB/2.*(DTT*2.*(1.-Y)*DWW)                                 FL    47
      PT(L)=PT(I)*EXP(PAK)                                               FL    48
      CALL MACH(I,W(L),PT(L),TT(L),EAF(L),RBETAL,SK,PG,EM(L),TS(L),PS(L) FL    49
     *,RHO(L),V(L),VX(L),VTHR,Q(L),QP(L))                                FL    50
      NIT=NIT+1                                                          FL    51
      BETA(L)=57.2957795*ATAN(VTH(L)/VX(L))                              FL    52
      IF (NIT.GE.10)GO TO 40                                             FL    53
      IF (NIT.EQ.1)GO TO 30                                              FL    54
      IF (ABS(BETA(L)-BETACH).GT..05)GO TO 30                            FL    55
   40 RETURN                                                             FL    56
C     END FLOW                                                           FL    57
      END                                                                FL    58
```

```
      SUBROUTINE MIX(I,L,WJW,Y)                                        MI        2
      COMMON/INPUTC/DP,BLKF,SK,RZ,FRIC,TANS,COB,NEL,TITLE(10),NELTOT,  CD2       2
     + NELEM(080),NETYP(080),RB(080),XO(080),XI(080),CL(080),RI(080),  CD2       3
     2 TLIN(080),BLKI(080),PBLK(080),WBPCT(080),NHOLES(080),NHTYP(080), CD2      4
     3 ISEP(080),IDBUG,NFW(080),IPIC,ABETA(080),SIGM,SIGN2,IRUN,ICASE  CD2       5
      COMMON/OUTPUT/PTDIS,CDOV,WCORRT,CUMGA,CUMWJ,RB(080),H(080),      CD2       5
     1 AX(080),BLKW(080),BLKS(080),EAX(080),EAF(080),BETA(080),PS(080), CD2      7
     2 W(080),TT(080),PT(080),TS(080),RHO(080),EM(080),V(080),VX(080), CD2       8
     3 VTH(080),Q(080),QP(080),BLKR(080),WL(080),WAKDEC(080),          CD2       9
     4 CD(080),ANGJ(080),DHOLES(080),AHOLES(080),EAH(080),CUMEA(080),  CD2      10
     5 VJET(080),ATCHL(080),XA(080),CUMLF                              CD2      11
      COMMON/CONBIT/IN,NOUT,IREAK,ITER,SWFF,SWFD                       CD2      12
      II=NELEM(I)                                                      MI        4
      RAD=57.2957795                                                   MI        5
      WJ=WBPCT(L)*W(II)                                                MI        5
      WJW=WJ/W(I)                                                      MI        7
      CPJ=.24                                                          MI        8
      CPG=.3                                                           MI        9
      HJ=CPJ*TT(II)                                                    MI       10
      HI=CPG*TT(I)                                                     MI       11
      HL=(W(I)*HI-WJ*HJ)/(W(I)-WJ)                                     MI       12
      TT(L)=HL/.3                                                      MI       13
      WRITE (61,10)CPJ,CPG,HJ,HI,HL,W(I),WJ,TT(II),TT(I),TT(L)         MI       14
      VJCA=VJET(L)*COS(ANGJ(L)/RAD)                                    MI       15
      VTHJ=ABS(VJCA*SIN(ABETA(L)/RAD))                                 MI       16
      VXJ=VJCA*COS(ABETA(L)/RAD)                                       MI       17
      IF (VJCA.GE.0.) BA=COS((ABETA(L)-BETA(I))/RAD)                   MI       18
      IF (VJCA.LT.0.) BA=COS((ABETA(L)+BETA(I))/RAD)                   MI       19
      VXI=VJCA*BA                                                      MI       20
      VTH(L)=(W(I)*VTH(I)-WJ*VTHJ)/(W(I)-WJ)                           MI       21
      Y=VXJ/VX(I)                                                      MI       22
      Y=VXI/V(I)                                                       MI       23
      WRITE(61,20)VTHJ,VXJ,VXI,VTH(L),Y                                MI       24
   20 FORMAT (22H VTHJ VXJ VXI VTH(L) Y ,5F10.5)                       MI       25
      RETURN                                                           MI       26
C                                                                      MI       27
   10 FORMAT (44H CPJ CPG HJ HI HL W(I) WJ TT(II) T(I) TT(L) ,/1X,2F6.3, MI     28
     +1X,2F10.3,1X,F12.3,1X,2F7.3,1X,3F12.3)                           MI       29
C     END MIX                                                          MI       30
      END                                                              MI       31
```

```
      SUBROUTINE JET(I,L,LL,WJW)
      COMMON/INPUTC/DP,BLKF,SK,RG,FRIC,TANS,COS,NEL,TITLE(10),NELTOT,
     + NELEM(080),NETYP(080),RD(080),XO(080),XI(080),CL(080),PI(080),
     2 TLIN(080),BLKI(080),DBLK(080),WBPCT(080),NHOLES(080),NHTYP(080),
     3 ISEP(080),IDBUG,NFW(080),IPIC,ABETA(080),SIGM,SIGM2,IRUN,ICASE
      COMMON/OUTPUT/PTDIS,CDGV,WCOPRI,CUMGA,CUMWJ,PR(080),H(080),
     1 AX(080),BLKW(080),BLKS(080),FAX(080),FAF(080),BETA(080),PS(080),
     2 W(080),TT(080),PT(080),TS(080),RHO(080),FM(080),V(080),VX(080),
     3 VTH(080),D(080),GP(080),BLKR(080),WL(080),WAKDEC(080),
     4 CD(080),ANGJ(080),DHOLES(080),AHOLES(080),EAH(080),CUMEA(080),
     5 VJET(080),ATCHL(080),XB(080),CUMLF
      COMMON/CODBIT/IN,NOUT,IPEAK,ITER,SWFF,SWFD
      LI=NELEM(1)
      NIT=0
      ITM=20
      C1= 2./(SK-1.)
      C2= (SK-1.)/SK
      C3=32.174*SK*RG
      WJ=WBPCT(L)*W(LI)
      IF (NFW(L).EQ.1HB)GO TO 95
      DPS=PS(I)-PTDIS
      IF (DPS.LE.0.) WRITE (61,130) L,DPS
  130 FORMAT ( 33H STATIC PRESSURE DROP AT ELEMENT ,I3, 21H ZERO OR NEGA
     *TIVE, = ,F12.5)
      PRJ=PT(I)/PTDIS
      IF (PRJ.GT.1.) GO TO 10
      WRITE (61,100) L
      IF (PRJ.EQ.1.) PRJ=.999999
      PRJ=1./PRJ
      EMJ=SQRT(C1*(PRJ**C2-1.))
      VJET(L)= EMJ*SQRT(C3*TS(I))
   35 IF (NFW(L).EQ.1HC) GO TO 37
      AHOLES(L)=0.
      DHOLES(L)=0.
      EAH(L)=0.
      IF (NFW(L).NE.1HC) WJ=0.
      WRITE(61,500) L
  500 FORMAT(1X,*FLOW ELEMENT *,I3,* HAS NEGATIVE PRESSURE DROP,  ORIFIC
     +E DIA AND FLOW SET TO ZERO. *)
      GO TO 70
   37 EAH(L)=AHOLES(L)*.1
      VJET(L)=SQRT(2.*32.174/RHO(I)*ABS(PTDIS-PS(I)))
      WJ=-EAH(L)*VJET(L)*RHO(I)/144.
      WRITE(61,501)L,WJ
  501 FORMAT(1X,*FLOW ELEMENT *,I3,* HAS NEGATIVE FLOW OF *,F12.6,* WITH
     + DISCH COEF SET TO 0.1*)
      GO TO 60
   10 EMJ=SQRT(C1*(PRJ**C2-1.))
      VJET(L)=EMJ*SQRT(C3*TS(I))
   20 AF=EAF(I)
      HV=V(I)/VJET(L)
      IF (NFW(L).EQ.1HD)GO TO 40
      WJW=WJ/W(I)
      EAH(L)=WJ/VJET(L)/RHO(I)*144.
      IF (HV.GE.1.) GO TO 35
      CALL DCDEF (HV,WJW,BLI,NHTYP(L),CD(L),ANGJ(L))
      AHAN=BLI
      CDH=CD(L)
   30 IF (CD(L).EQ.0.) CDH= .0001
      AHOLES(L)=EAH(L)/CDH
      AHOLE=AHOLES(L)/NHOLES(L)
      DHOLES(L)=SQRT(AHOLE/.7853982)
      SWFF=SWFF+WBPCT(L)
 1000 FORMAT(19H AH AHOLES CD AHAN ,4(F20.10,1X))
      GO TO 70
   40 AHOLE=.7853981*DHOLES(L)*DHOLES(L)
      AHOLES(L)=AHOLE*NHOLES(L)
      AHAN=AHOLES(L)/AF
      WJE=WJ
   50 WJW=WJE/W(I)
      IF (HV.GT.1.) GO TO 35
      IF (WJE.LE.0.) WJW=.05*W(LI)/W(I)
      CALL DCDEF (HV,WJW,BLI,NHTYP(L),CD(L),ANGJ(L))
      EAH(L)=AHOLES(L)*CD(L)
      WJ=EAH(L)*VJET(L)*RHO(I)/144.
 2000 FORMAT(1X,I3,21HD AHAN BLI CD EAH WJ ,5(F20.5,1X))
      IF (ABS(WJE-WJ).LT..0001)GO TO 60
```

```
      WJE=WJ
      IF (NIT.GT.ITM)GO TO 60
      NIT=NIT+1
      GO TO 50
   60 WJW=WJ/W(I)
      IF (WJW.GT.1.)WRITE (61,110)L
      WBPCT(L)=WJ/W(LI)
      SWFO=SWFO+WBPCT(L)
   70 CUMWJ=CUMWJ+dJ
      CUMLF=CUMLF+WJ
      CUMGA=CUMGA+AHOLES(L)
      CUMEA(L)=0.
      IF (I.GT.LL)GO TO 5
      DO 80 NN=1,LL
      N=NELEM(NN)
   80 CUMEA(L)=CUMEA(L)+EAN(N)
    5 CONTINUE
      IF (NIT.GE.ITM) WRITE(61,120)L
      RETURN
   90 CUMWJ=CUMWJ+WJ
      WJW=WJ/W(I)
      SWFF=SWFF+WBPCT(L)
      RETURN
C
  100 FORMAT (   67H ANNULUS TOTAL PRESSURE LESS THAN LINER STATIC PRESS
     +URE AT ELEMENT ,I3)
  110 FORMAT(1X,*PRESSURE DROP TOO HIGH. TOTAL ORF FLOW AT ELEMENT *,I3,
     +* EXCEEDS INLET FLOW*)
  120 FORMAT (46H  ITERATIONS IN JET EXCEEDED LIMIT AT ELEMENT ,I3,/)
      END  JET
C
      END
```

```
      SUBROUTINE DCOEF (W,WJW,BLI,NHOTYP,CDJ,AJET)
      W=WJW
      ICKCGT=NHOTYP
      IF (ICKCGT.LE.1)GO TO 10
      IF(ICKCGT.GT.6) GO TO 73
      GO TO (10,10,10,10,60,10),ICKCGT
   10 PI=3.141592654
      RAD=57.2957795131
      IF (WJW.GT.1.)W=1.
      IF (W.LE.0.)GO TO 70
      IF(W.GT.1.) GO TO 70
      BLD=ACOS(1.-W/2.)*RAD
      R=ACOS(W*(1.-W/2.))
      B=R*RAD
      C1=COS(R)
      C2=1.-W/2.
      C3=1.-W
      C4=SIN(R)
      C5=(1.+C1)/(1.-C1)
      C6=(C2*C2+C1*C1)/(C2*C1)
      C7=(C2+C1)/(C2-C1)
      C8=(C2*C2+C3*C3*C1*C1)/C2/C1
      C9=(C2+C3*C1)/(C2-C3*C1)
      BL=C1/PI/C2*((PI*C4*W)-C1*W*ALOG(C5)+C6*ALOG(C7)-C8*ALOG(C9))
      BLI=BL
   30 CKB=2.*COS(R)/(BLI*(2./W-1.))
      CDJ=CKB
      AJET=B
      IF(NHOTYP.EQ.2)GO TO 40
      IF(NHOTYP.EQ.3)GO TO 50
      IF(NHOTYP.EQ.4)GO TO 52
      IF(NHOTYP.EQ.6) GO TO 54
C     HOLE TYPE 1, FLUSH HOLE, THIN WALL
      RETURN
C     HOLE TYPE 2, PLUNGED HOLE
   40 CDJ=CDJ*1.475
      AJET=80.
      RETURN
C     HOLE TYPE 3, COOLING SKIRT
   50 CDJ=CDJ*1.4
      AJET=G.
      RETURN
C     HOLE TYPE 4, FLUSH HOLE, THICK WALL
   52 CDJ=CDJ
      AJET=80.
      RETURN
C     HOLE TYPE 6, RECTANGULAR, THICK WALL
   54 CDJ=CDJ*1.1
      AJET=60.
      RETURN
C     HOLE TYPE 5, INPUT CD, SET JET ANGLE ONLY
   60 AJET=90.
      RETURN
   70 CDJ=0.
      AJET=0.
      RETURN
C
C     END DCOEF
      END
```

```
      SUBROUTINE DELTO(T1,V,RHO,H,PI,CL,W,TW,T2,DTT,FRIC,FF,NFUT)      DE   2
      TKO=.0264*(T1/1000.)**.84                                        DE   3
      VISO=1.05E-5*(T1/1000.)**.65                                     DE   4
      REV=2.*H/12.*RHO*V/VISO                                          DE   5
      IF (NFUT.EQ.1HC)GO TO 10                                         DE   6
      HO=TKO/2./(H/12.)*.0154*(REV**.8)                                DE   7
      AW=2.*3.1415926*PI*CL/144.                                       DE   8
      O=HO*AW/(W*3600.)/.24                                            DE   9
      T2=TW-(TW-T1)/(EXP(O))                                           DE  10
      GO TO 20                                                         DE  11
   10 T2=TW+T1                                                         DE  12
   20 DTT=ALOG(T2/T1)                                                  DE  13
      IF (FRIC.LT.0.)GO TO 50                                          DE  14
      PSRFFE=SQRT(REV**.25/.0791)                                      DE  15
   30 PSRFF=3.48-4.*ALOG10(FRIC+9.35*PSRFFE/REV)                       DE  16
      IF (ABS(PSRFF-PSRFFE)/PSRFF.LT..01)GO TO 40                      DE  17
      PSRFFE=PSRFF                                                     DE  18
      GO TO 30                                                         DE  19
   40 FF=1./PSRFF/PSRFF                                                DE  20
      RETURN                                                           DE  21
   50 FF=0.                                                            DE  22
      RETURN                                                           DE  23
C     END DELTO                                                        DE  24
      END                                                              DE  25
```

```
      SUBROUTINE AKM(DAA,DTT,DF,DWW,Y,SK,EM1,EMB,EM2)              AK       2
      FA=-2.                                                         AK       3
      BIGK=(1.+(SK-1.)/2.*EMB)/(1.-EMB)                              AK       4
      EMI=EM1                                                        AK       5
      FF=SK*EMB                                                      AK       6
      FT=1.+FF                                                       AK       7
      FW=2.*(1.+FF*(1.-Y))                                           AK       8
      ALPHA=FA*DAA+FT*DTT+FF*DF+FW*DWW                               AK       9
      AK=ALPHA*BIGK                                                  AK      10
      EM2=EM1*EXP(AK/2.)                                             AK      11
      IF (EM2.GE.1.)GO TO 40                                         AK      12
   30 RETURN                                                         AK      13
   40 WRITE (61,50)AK,DAA,DTT,DF,DWW,EM1,EM2                         AK      14
      RETURN                                                         AK      15
C                                                                    AK      16
   50 FORMAT (43H   MACH NO. EXCEEDS 1 AND WILL NOT CONVERGE,/19H    AK      17
     +  ALPHA-K  = ,F13.6,10X,7HDA/A  = ,F13.6/19H        DT/T    = ,F13. AK      18
     +6,10X,7HDF    = ,F13.6/19H          DW/W    = ,F13.6,10X,7HM 1  = ,F AK      19
     +13.6/19H          M 2     = ,F13.6,/)                          AK      20
C                                                                    AK      21
      END AKM                                                        AK      22
      END
```

SUBROUTINE MACH 73/74 OPT=1 TRACE FTN 4.6+439 09/26/79 09.58.39 PAGE 1

```
      SUBROUTINE MACH(IMACH,W,PT,TT,A,RBETA,SK,R,EM,TS,PS,RHO,V,VX,VTH,Q    MAC  2
     *,QP)                                                                  MAC  3
      C1=W/A/PT*SQRT(R*TT/SK/32.174)                                        MAC  4
      C2=(SK+1.)/2./(SK-1.)                                                 MAC  5
      C3=(SK-1.)/2.                                                         MAC  6
      IF (IMACH.EQ.1)GO TO 10                                               MAC  7
      EM=C1                                                                 MAC  8
   10 C4=1.+C3*EM*EM                                                        MAC  9
      C5=SK/(SK-1.)                                                         MAC 10
      C4C2=C4**C2                                                           MAC 11
      IF (IMACH.EQ.1)GO TO 20                                               MAC 12
      ERR=EM/C4C2-C1                                                        MAC 13
      DERR=(1.-(2.*EM*EM*C2*C3)/C4)/C4C2                                    MAC 14
      EM=EM-ERR/DERR                                                        MAC 15
      IF (ABS(ERR/DERR).GT..0001)GO TO 10                                   MAC 16
   20 TS=TT/C4                                                              MAC 17
      PS=PT/(C4**C5)                                                        MAC 18
      RHO=144.*PS/R/TS                                                      MAC 19
      V=W/RHO/A*144.                                                        MAC 20
      VX=V*COS(RBETA)                                                       MAC 21
      VTH=V*SIN(RBETA)                                                      MAC 22
      Q=RHO*V*V/(2.*32.174*144.)                                            MAC 23
      QP=Q/PT                                                               MAC 24
      RETURN                                                                MAC 25
C     END MACH                                                              MAC 26
      END                                                                   MAC 27
```

SUBROUTINE XAREA 73/74 OPT=0 TRACE FTN 4.6+439 08/24/78 09.58.30 PAGE 1

```
      SUBROUTINE XAREA(RO,RI,ZO,ZI,RB,H,AX,XB)
      PI=3.14159265                                          XA   2
      RB=ABS((RO+RI)/2.)                                     XA   3
      H=SQRT((ZO-ZI)*(ZO-ZI)+(RO-RI)*(RO-RI))                XA   4
      AX=2.*PI*RB*H                                          XA   5
      XB=(ZO+ZI)/2.                                          XA   6
      RETURN                                                 XA   7
C     END XAREA                                              XA   8
      END                                                    XA   9
                                                             XA  10
```

SUBROUTINE PROUT 73/74 OPT=0 TRACE FTN 4.6+439 08/24/79 09.55.33 PAGE

```
      SUBROUTINE PROUT(LM)
      COMMON/INPUTC/DP,BLKF,SK,RG,FRIC,TANS,CDR,NFL,TITLE(10),NELTOT,
     * NELEM(080),NETYP(080),RO(080),XO(080),XI(080),CL(080),RI(080),
     2 TLIM(080),BLKI(080),DBLK(080),WBPCT(080),NHOLES(080),NHTYP(080),
     3 ISEP(080),IDBUG,NFW(080),IPIC,ABETA(080),SIGN,SIGN2,IRUN,ICASE
      COMMON/OUTPUT/PTDIS,CDOV,WCORRI,CUMSA,CUMVJ,RR(080),H(080),
     1 AX(080),BLKW(080),BLKS(080),EAX(080),EAF(080),BETA(080),PS(080),
     2 W(080),TT(080),PT(080),TS(080),RHO(080),EM(080),V(080),VX(080),
     3 VTH(080),Q(080),QP(080),BLKM(080),WL(080),WAKDEC(080),
     4 CD(080),ANGJ(080),DHOLES(080),AHOLES(080),FAH(080),CUMEA(080),
     5 VJET(080),ATCHL(080),RB(080),CUMEF
      COMMON/CODBIT/IN,NOUT,IFFAX,ITER,SWFF,SWFD
      WRITE (61,40)TITLE
      IF (1.GT.LM)GO TO 5
      DO 10 LL=1,LM
      L=NELEM(LL)
   10 WRITE (61,50)NELEM(LL),NETYP(L),NFW(L),BETA(L),W(L),EM(L),V(L),VX(
     +L),VTH(L),TT(L),TS(L),PT(L),PS(L),RHO(L),Q(L),QP(L)
    5 CONTINUE
      WRITE (61,60)TITLE
      IF (1.GT.LM)GO TO 15
      DO 30 LL=1,LM
      L=NELEM(LL)
      IF (NETYP(L).EQ.IMF)GO TO 20
      WRITE (61,70)NELEM(LL),NETYP(L),NFW(L),RR(L),H(L),AX(L),EAF(L),BLK
     +W(L),BLKS(L),ATCHL(L)
      GO TO 30
   20 WRITE (61,70)NELEM(LL),NETYP(L),NFW(L),RR(L),H(L),AX(L),EAF(L),BLK
     +W(L),BLKS(L),ATCHL(L),DHOLES(L),CD(L),ANGJ(L),AHOLES(L),FAH(L),CUM
     +EA(L),VJET(L),WBPCT(L)
   30 CONTINUE
   15 CONTINUE
      WRITE (61,80)CDOV,WCORRI,PTDIS,DP,CUMSA
      RETURN
C
   40 FORMAT (1H1,1X,10A8//10X,23HOUTPUT RESULTS - PAGE 1,//116H ELEM  E
     +LEM  SWIRL    FLOW      MACH    FLOW     AXIAL     TANG     TOTAL    STATI
     +C  TOTAL    STATIC   DENSITY  DYNAM   37H 40,/116H  NO    TYPE  ANGLE
     +    RATE          NO      VEL       VEL        VEL       TEMP,     TEMP,     PRESS,
     + PRESS,                 HEAD,    /PTOT ,/115H                          LB/S
     +              FPS         FPS        FPS        R          R         PSIA      PSIA     L
     +B/FT3    PSIA          --    ,/)
   50 FORMAT (1X,I3,4X,A1,A1,2X,F6.2,2X,F7.3,2X,F5.4,1X,F7.2,1X,F7.2,1X,
     +F7.2,2X,F6.1,2X,F6.1,2X,F6.2,2X,F5.2,2X,F7.4,2X,F6.3,2X,F6.4)
   60 FORMAT (1H1,1X,10A8//10X,23HOUTPUT RESULTS - PAGE 2,//10X,1H/,1H*,
     +1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1X,29HANNULUS GEOMETRIC PARAME
     +TERS,1X,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1X,1H/,1X,1H*,1H*,1H*,1H*,
     +1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1X,1HH
     +ORIFICE PARAMETERS,1X,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,
     +1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1H*,1X,1H/,/1X,61HELEM ELEM MEAN
     + CHANNEL ANN    AN EFF WAKE     SEPAR  ATTCH    ,59HHOLE     DISCH   JE
     +T      ORIF       ORIF       ORIF        JET         ORIF,/1X,61H NO.  TYPE RADIUS
     +    WIDTH   AREA     AREA   AREA     AREA    LENGTH    ,59HDIAM      COEFF    ANG
     +LE    GEOM       EFF          CUMUL   VELOCITY   FLOW,/1X,61H                  IN.
     +     IN.     IN2       IN2     FACTOR FACTOR     IN.        ,59H IN.           -          DE
     +G      AREA        AREA      EF AREA      FPS         /AIN,/)
   70 FORMAT (1X,I3,3X,A1,A1,1X,F7.3,1X,F5.3,2X,F6.2,1X,F6.2,1X,F5.3,2X,
     +F5.3,1X,F7.3,1X,F7.4,1X,F5.4,1X,F6.2,1X,F7.3,1X,F7.3,1X,F8.3,1X,F7
     +.2,1X,F7.4)
   80 FORMAT (20X,29HOVERALL FLOW COEFFICIENT =     ,F6.4/20X,29HINLET COR
     +RECTED FLOW, LB/S = ,F7.3/20X,29HDISCHARGE PRESSURE, PSIA =     ,F6.
     +2/20X,29HPRESSURE DROP / PT INLET     = ,F7.4/20X,29HTOTAL GEOMETRIC
     + AREA, IN2 =    ,F8.3/)
C     END PROUT
      END
```

```
      SUBROUTINE PICTUR
      COMMON/CPICT/XNO,YNO,XFV,YFV,XOV,YOV,XBB(080),YBB(080),XG,YG,
     1  SIZE,XTI,YTI,XMOVE,YMOVE,DATA(12),PCYL(1,1)
      COMMON/INPUTC/DP,BLKF,SK,PG,FPIC,TANS,CON,NEL,TITLE(10),NELTOT,
     +  NELEM(080),NETYP(080),PO(080),XO(080),XI(080),CL(080),PI(080),
     2  TLIN(080),SLPI(080),DRLK(080),DBPCT(080),NHOLES(080),NNTYP(080),
     3  ISEP(080),IDBUG,NFA(080),IPIC,ARETA(080),SIGN,SIGN2,IRUN,ICASE
      COMMON/CUTPUT/PTDIS,CDOV,NCOMP,CUMGA,CUMWJ,RE(080),NI(080),
     1  AX(080),BLKW(080),BLKS(080),EAX(080),EAF(080),BETA(080),PS(080),
     2  W(080),TT(080),PT(080),TS(080),PMD(080),EM(080),V(080),VX(080),
     3  VTH(080),Q(080),QP(080),PLMN(080),W (080),MAXDEC(080),
     4  CD(080),ANGJ(080),DHOLES(080),ANDLFS(080),EAM(080),CUMEA(080),
     5  VJET(080),ATCHL(080),TA(080),CUMLF
      COMMON/CODRIT/IN,NOUT,IPFAT,ITEP,SWEF,SWEC
C     ----------------------------------------------------------------
      ENTRY PICTUR1
C --------   DATA INITIALIZATION  ---------
      WBOX=0.9
      HBOX=3.875
      ILB=0
      ILT=0
      SPAC1=.125
      SPAC2=.5
      WINPUT=5.0
      WNCM=4.0
      XMAX=-1000.
      RMAX=-1000.
      XMIN=1000.
      RMIN=10000.
      WTOT=WBOX+SPAC1
      IDONE=0
C     ------------------------
      DO 1000 I=1,NEL
      IM=MAX0(1,I-1)
      LL=NELEM(I)
      LLM=NELEM(IM)
      RMAX=AMAX1(RMAX,PO(LL),PI(LL))
      RMIN=AMIN1(RMIN,RO(LL),RI(LL))
      XMAX=AMAX1(XMAX,XO(LL),XI(LL))
      XMIN=AMIN1(XMIN,XO(LL),XI(LL))
      IF (RI(LL).GT.RO(LL)) GO TO 1010
C  -------     UPPER HALF OF ANNULUS  --------
      IDONE=1
      IF (NETYP(LL).EQ.IML) ILT=ILT+1
      IF (NETYP(LL).EQ.IMF.AND.NETYP(LLM).EQ.IMF)  ILT=ILT+1
      GO TO 1000
C ---------   LOWER HALF OF ANNULUS  ---------
 1010 IF (NETYP(LL).EQ.IML) ILB=ILB+1
      IF (NETYP(LL).EQ.IMF.AND.NETYP(LLM).EQ.IMF) ILB=ILB+1
 1000 CONTINUE
      IDONP=IDONE+1
C -------    DETERMINE MAXIMUM WIDTH OF TOTAL PLOT  -------
      WPIC=XMAX-XMIN+SPAC2
      HPIC=RMAX-RMIN+SPAC2
      HPIC=AMAX1(HPIC,3.7)
      WTOP=WTOT*FLOAT(ILT)
      WMD=WINPUT+WNCM+WPIC+SPAC2+SPAC2
      WBOTM=WTOT*FLOAT(ILB)
      WMAX=AMAX1(WTOP,WMD,WBOTM)
C  -------     ESTABLISH MASTER PLOT ORIGIN  -------
      XMO=WMAX/2.+1.0
      RTOT=2.*(HBOX+SPAC2)+HPIC
      RMO=RTOT/2.+2.0
      FMULT=AMIN1(1.0,25./RTOT)
      CALL FACTOR(FMULT)
      CALL PLOT (XMO,RMO,-3)
C ---------    DETERMINE XBB AND YBB  (BOX LOCATIONS)   ------------
      IF (IDONE.EQ.0) GO TO 1027
      LL=NELEM(1)
      RBL=HPIC/2.+SPAC2
      RBF=RBL+2.1+SPAC1
      YBB(LL)=RBL
      XBB(LL)=-WTOP/2.
      DO 1020 I=2,IDONE
      LL=NELEM(I)
      LLM=NELEM(I-1)
      IF (NETYP(LL).EQ.IML) YBB(LL)=RBL
```

```
      IF (METYP(LL).EQ.INF) YBB(LL)=PBF
      IF (METYP(LL).EQ.INL) XBB(LL)=XBB(LL-M)+WTOT
      IF (METYP(LL).EQ.INF.AND.METYP(LL-M).EQ.INF) XBB(LL)=XBB(LL-M)+WTOT
      IF (METYP(LL).EQ.INF.AND.METYP(LL-M).EQ.INL) XBB(LL)=XBB(LL-M)
 1020 CONTINUE
 1027 XBL=-WPIC/2.-SPAC2-2.1
      XBF=XBL-1.05-SPAC1
      IF (IDONE.GE.NEL) GO TO 1030
      LL=NELEM(IDONE)
      XBB(LL)=WBOTM/2.
      IF (IDONE.GT.0) GO TO 1028
      XBB(LL)=-WBOTM/2.
      WTOT=-WTOT
 1028 IF (METYP(LL).EQ.INL) YBB(LL)=PBL
      IF (METYP(LL).EQ.INF) YBB(LL)=PBF
      IDONPP=IDONE+1
      DO 1025 I=IDONPP,NEL
      LL=NELEM(I)
      LLM=NELEM(I-1)
      IF (METYP(LL).EQ.INL) YBB(LL)=PBL
      IF (METYP(LL).EQ.INF) YBB(LL)=PBF
      IF (METYP(LL).EQ.INL) XBB(LL)=XBB(LL-M)-WTOT
      IF (METYP(LL).EQ.INF.AND.METYP(LL-M).EQ.INF) XBB(LL)=XBB(LL-M)-WTOT
      IF (METYP(LL).EQ.INF.AND.METYP(LL-M).EQ.INL) XBB(LL)=XBB(LL-M)
 1025 CONTINUE
C ------- INITIALIZE DATA LOCATIONS --------
 1030 XNO=WPIC/2.+SPAC2+0.2
      YNO=-1.35
      XFV=-WPIC/2.-SPAC2-4.0-SPAC2
      YFV=SPAC2
      XOV=XFV
      YOV=-SPAC2-1.0
      XS=0.
      YS=0.
      SIZE=0.
      XTI=-4.7
      YTI=WPIC/2.+SPAC2+HBCX+SPAC1
      XMOVE=1.1*XMS
      YMOVE=-HMS
C ------- DRAW PICTURE --------
      PMEAN=0.5*(PMAX+PMIN)
      XMEAN=0.5*(XMAX+XMIN)
      DO 1049 I=1,NEL
      LL=NELEM(I)
      PO(LL)=PO(LL)-PMEAN
      PI(LL)=PI(LL)-PMEAN
      XO(LL)=XO(LL)-XMEAN
      XI(LL)=XI(LL)-XMEAN
 1049 CONTINUE
      LL=NELEM(1)
      POA=PO(LL)+PMEAN
      YY=PO(LL)
      XX=XO(LL)-SPAC2
      CALL NUMBER (XX,YY,0.1,POA,0.,2)
      POA=PI(LL)+PMEAN
      YY=PI(LL)
      XX=XI(LL)-SPAC2
      CALL NUMBER (XX,YY,0.1,POA,0.,2)
      CALL PLOT (XI(LL),PI(LL),+3)
      DO 1050 I=2,NEL
      LL=NELEM(I)
      CALL PLOT (XI(LL),PI(LL),+2)
 1050 CONTINUE
      LL=NELEM(1)
      CALL PLOT (XO(LL),PO(LL),+3)
      DO 1060 I=2,NEL
      LL=NELEM(I)
      CALL PLOT (XO(LL),PO(LL),+2)
 1060 CONTINUE
      IF (IDONE.GE.NEL) GO TO 1065
      LL=NELEM(NEL)
      POA=PO(LL)+PMEAN
      YY=PO(LL)
      XX=XO(LL)-SPAC2
      CALL NUMBER (XX,YY,0.1,POA,0.,2)
      POA=PI(LL)+PMEAN
      YY=PI(LL)
```

```
      XX=XI(LL)-SPAC2
      CALL NUMBER (XX,YY,0.1,RDA,0.,2)                              PI      146
 1065 CONTINUE                                                      PI      147
C ---------   RESTORE VALUSE OF R'S AND X'S  -----------            PI      148
      DO 1070 I=1,NEL                                               PI      149
      LL=NELEM(I)                                                   PI      150
      RO(LL)=RO(LL)+RMEAN                                           PI      151
      RI(LL)=RI(LL)+RMEAN                                           PI      152
      XO(LL)=XO(LL)+XMEAN                                           PI      153
      XI(LL)=XI(LL)+XMEAN                                           PI      154
      XB(LL)=XB(LL)-XMEAN                                           PI      155
      RB(LL)=RB(LL)-RMEAN                                           PI      156
 1070 CONTINUE                                                      PI      157
C ---------   DRAW BOXES  ------                                    PI      158
      CALL BOXES                                                    PI      159
      RETURN                                                        PI      160
C     END CONDPT                                                    PI      161
      END                                                           PI      162
```

SUBROUTINE BOXES   73/74   OPT=0 TRACE   FTN 4.6+439   08/24/79 09.59.39   PAGE   1

```
      SUBROUTINE BOXES                                                  BD           2
      COMMON/CPICT/XNO,YNO,XFV,YFV,XOV,YOV,XBB(080),YBB(080),XG,YG,    CD1          2
     1  SIZE,XTI,YTI,XMOVE,YMOVE,DATA(12),FKYL(1,1)                     CD1          3
      COMMON/INPUTC/DP,BLKF,SK,RG,FRIC,TANS,CDR,NEL,TITLE(10),NELTOT,   CD2          2
     +  NELEM(080),NETYP(080),RD(080),XD(080),XT(080),CL(080),PI(080),  CD2          3
     2  TC(N(080),ELKI(080),DALK(080),WRPCT(080),NHOLES(080),NHTYP(080),CD2          4
     3  ISEP(080),IDBUG,NFW(080),IPIC,ANETA(080),SIGN,SIGN2,IRUN,ICASE  CD2          5
      COMMON/OUTPUT/PTDIS,CDOV,WCORRI,CUMGA,CUMWJ,WW(080),H(080),       CD2          6
     1  AX(080),BLKW(080),BLKS(080),EAX(080),EAF(080),BETA(080),PS(080),CD2          7
     2  W(080),TT(080),PT(080),TS(080),RHO(080),EM(080),V(080),VX(080), CD2          8
     3  VTH(080),Q(080),QP(080),BL  M(080),V (080),DAKDEC(080),         CD2          9
     4  CD(080),ANGJ(080),DHOLES(080),AHOLES(080),EAH(080),CUMEA(080),  CD2         10
     5  VJET(080),ATCHL(080),XM(080),CUMLF                              CD2         11
      COMMON/CODBIT/IN,NOUT,IREAX,ITER,SWFF,SWFD                        CD2         12
      DIMENSION NOM(4),NOMEN(4,19),NOMF(5),NOMENF(5,6),NOMO(4),NOMENO(4,BD           5
     +5),FIV(6),DOV(5)                                                  BD           6
      DIMENSION YT(4),YN(11),XBOX(7),YBOXL(7),YBOXF(7),NDL(11),NDF(8),NABD           7
     +M(19),NHD(4),ENUM(11),FNUF(9)                                     BD           8
      DIMENSION XPB(080),YPB(080)                                       BD           9
      DATA YH    /1.95,1.8,1.50,1.35/                                   BD          10
      DATA YN    /.05,.2,.35,.5,.65,.8,.95,1.1,1.25,1.4,1.55/           BD          11
      DATA XBOX    /.9,.9,0.,0.,.9,0.,0./                               BD          12
      DATA YBOXL    /0.,2.1,2.1,1.75,1.75,1.75,0./                      BD          13
      DATA YBOXF    /0.,1.65,1.65,1.3,1.3,1.3,0./                       BD          14
      DATA NDL    /4,3,0,0,0,2,3,2,2,0,3/                               BD          15
      DATA NDF    /0,2,3,3,3,4,-1,4/                                    BD          16
      DATA NAM    /2HQ ,2HQE,2HTV,2HAV,2HV ,2HSA,2HM ,2HPS,2HPT,2HTT,2HW BD          17
     +,2HJV,2HJA,2HCO,2HEA,2HGA,2HDD,2HNO,2HNO/                         BD          18
      DATA NHD    /5HINLET    ,8HANNULUS ,9HORIFICE ,4HELEM/            BD          19
      DATA NOMEN      /8HJET INJE,8HCTION VE,8HLOCITY, ,8HFPS      ,8HJET BD          20
     +INJE,8HCTION AN,8HGLE, DEG,8HREES     ,8HORIFICE ,8HDISCHARG,8HE CO BD          21
     +EFFI,8HCIENT    ,8HSTATION ,8HEFFECTIV,9HE AREA, ,8HSQ. IN. ,8HSTAT BD          22
     +ION ,8HGEOMETRI,8HC AREA, ,9HSQ. IN. ,8HORIFICE ,8HDIAMETER,8H, IN BD          23
     +.   ,8H         ,8HNUMBER O,8HF ORIFIC,8HES     ,8H         ,8HORIF BD          24
     +ICE ,8HFLOW / I,8HNLET FLO,8HW       ,8HDYNAMIC ,8HHEAD / P,8HT CO BD          25
     +CAL ,8H         ,8HDENSITY,,8H LB/CU F,8HT      ,8H        ,8HTANG BD          26
     +ENTI,8HAL FLOW ,8HVELOCITY,8H, FPS    ,8HAXIAL FL,8HOW VELOC,8HITY, BD          27
     + FPS,8H         ,8HTOTAL FL,8HOW VELOC,8HITY, FPS,8H       ,8HSWIR BD          28
     +L AN,8HGLE, DEG,8HREES FPO,8HM AXIAL ,8HMACH NUM,8HBER      ,8H     BD          29
     +    ,8H         ,8HSTATIC P,8HRESSURE,,8H PSIA   ,8H       ,8HTOTA BD          30
     +L PR,8HESSURE, ,8HPSIA     ,8H        ,8HTOTAL TE,8HMPERATUR,8HE, R BD          31
     +    ,8H         ,8HAIR MASS,8H FLOW RA,8HTE, LB/S,8HEC      /       BD          32
      DATA NOMENF     /8HAIR GAS ,8HCONSTANT,8H          ,8H         ,8H  BD          33
     +     =,8HAIR RATI,8HO OF SPE,8HCIFIC HE,8HATS      ,8H        =,8HDRA BD          34
     +G COE,8HFFICIENT,8H FOR INS,8HERTED BL,8HOCKAGE =,8HTANGENT ,8HCF   BD          35
     +SEPAR,8HATION SP,8HREAD ANG,8HLE        =,8HANNULUS ,8HEFFECTIV,8HE A BD          36
     +REA F,8HACTOR    ,8H         =,8HANNULUS ,8HWALL ROU,8HGHNESS F,8HACT BD          37
     +OR    ,8H          =/                                              BD          38
      DATA NOMENO      /8HDISCHARG,8HE PRESSU,8HRE, PSIA,4H    =,8HOVERALL BD          39
     + ,8HFLOW COE,8HFFICIENT,4H    =,8HTOTAL GE,8HOMETRIC ,8HAREA, IN,4H BD          40
     +2   =,8HOVERALL ,8HPRESSURE,8H DROP    ,4H    =,8HINLET CO,8HRRECTED BD          41
     +,8HFLOW, LB,4H/S =/                                               BD          42
      DO 4 I=1,NEL                                                      BD          43
      LL=NELEM(I)                                                       BD          44
      XPB(I)=XBB(LL)                                                    BD          45
      YPB(I)=YBB(LL)                                                    BD          46
    4 CONTINUE                                                          BD          47
      WRITE (61,140)XNO,YNO,XFV,YFV,XOV,YOV,XG,YG,SIZE,XTI,YTI,XMOVE,YMO BD          48
     +VE,(XPB(L),YPB(L),NELEM(L),L=1,NEL)                               BD          49
      XNA=.05                                                           BD          50
      XNU=.3                                                            BD          51
      XL=.45                                                            BD          52
      XDF=.78                                                           BD          53
      X=XNO                                                             BD          54
      Y=YNO                                                             BD          55
      XEQ=X+.3                                                          BD          56
      XNOM=X+.5                                                         BD          57
      NN=12                                                             BD          58
      DO 20 I=1,19                                                      BD          59
      CALL SYMBB(X,Y,.1,NAM(NN),0.,2)                                   BD          60
      CALL SYMBB(XEQ,Y,.1,1H=,0.,1)                                     BD          61
      NN=NN+1                                                           BD          62
      IF (NN.EQ.20) NN=1                                                BD          63
      DO 10 J=1,4                                                       BD          64
   10 NOM(J)=NOMEN(J,I)                                                 BD          65
      CALL SYMBR(XNOM,Y,.1,NOM,0.,32)                                   BD          66
   20 Y=Y+.15                                                           BD          67
```

```
      Y=Y+.15
      CALL SYMBB(X,Y,.1,43HORIFICE ELEMENT XX B - BLEED FLOW EXTRACTED,0
     +.,43)
      Y=Y+.15
      CALL SYMBB(X,Y,.1,42HORIFICE ELEMENT XX D - FIXED HOLE DIAMETER,0.
     +,42)
      Y=Y+.15
      CALL SYMBB(X,Y,.1,42HORIFICE ELEMENT XX F - FIXED FLOW PERCENT ,0.
     +,42)
      Y=Y+.3
      X=X-.2
      CALL SYMBB(X,Y,.1,12HNOMENCLATURE,0.,12)
      FIV(1)=PG
      FIV(2)=SK
      FIV(3)=CDB
      FIV(4)=TAMS
      FIV(5)=BLEF
      FIV(6)=FRIC
      X=XFV
      Y=YFV
      XNUP=X+4.1
      DO 40 I=1,6
      DO 30 J=1,5
   30 NOMF(J)=NOMENF(J,I)
      CALL SYMBB(X,Y,.1,NOMF,0.,50)
      CALL NUMBER(XNUP,Y,.1,FIV(I),0.,4)
   40 Y=Y+.15
      Y=Y+.15
      X=X-.2
      CALL SYMBB(X,Y,.1,20HFIXED INPUT VALUES -,0.,20)
      DOV(1)=PTDIS
      DOV(2)=CDDV
      DOV(3)=CUMGA
      DOV(4)=DP
      DOV(5)=WCORRI
      X=XDV
      Y=YDV
      XNUP=X+2.9
      DO 60 I=1,5
      DO 50 J=1,4
   50 NOMD(J)=NOMEND(J,I)
      CALL SYMBB(X,Y,.1,NOMD,0.,20)
      CALL NUMBER(XNUP,Y,.1,DOV(I),0.,4)
   60 Y=Y+.15
      Y=Y+.15
      X=X-.2
      CALL SYMBB(X,Y,.1,23HOVERALL OUTPUT VALUES -,0.,23)
      IF (1.GT.NEL)GO TO 5
      DO 130 LE=1,NEL
      LL=NELEM(LE)
      L=LL
      IF (XBB(L) .EQ. 0.0 .AND. YBB(L) .EQ. 0.0) GO TO 130
      ENUP(1)=SP(LL)
      ENUP(2)=SMCH(LL)
      ENUP(3)=VTH(LL)
      ENUP(4)=VX(LL)
      ENUP(5)=V(LL)
      ENUP(6)=BETA(LL)
      ENUP(7)=EM(LL)
      ENUP(8)=PS(LL)
      ENUP(9)=PT(LL)
      ENUP(10)=TT(LL)
      ENUP(11)=W(LL)
      FNUP(1)=VJET(LL)
      FNUP(2)=ANGJ(LL)
      FNUP(3)=CD(LL)
      FNUP(4)=EAH(LL)
      FNUP(5)=AHOLES(LL)
      FNUP(6)=DHOLES(LL)
      FNUP(7)=NHOLES(LL)
      FNUP(8)=WBPCT(LL)
      YCT=YBB(L)
      IF (XBB(LL).GT.YBB(L).AND.NETYP(LL).EQ.1HL)YCT=YCT+2.1
      IF (NETYP(LL).EQ.1HL) CALL PLOT (XBB(L),BB(LL),3)
      IF (NETYP(LL).EQ.1HL)CALL PLOT(XBB(L),YCT,2)
      IF (NETYP(LL).EQ.1HL)GO TO 70
      IF (NETYP(LL).EQ.1HF)GO TO 130
```

SUBROUTINE BOXES 73/74 OPT=1 TRACE FTN 4.6+439 08/26/78 09.58.39 PAGE 3

```
      GO TO 130
   70 CALL PLOT(XBB(L),YBB(L),3)
      DO 80 M=1,7
      X=XBB(L)+XBOX(M)
      Y=YBB(L)+YBOX(M)
   80 CALL PLOT(X,Y,2)
      X=XBB(L)+XMA
      XU=XBB(L)+XMU
      DO 90 M=1,11
      Y=YBB(L)+YP(M)
      CALL SYMBOL(X,Y,.1,NAM(M),0.,2)
   90 CALL NUMBER(XU,Y,.1,ENUM(M),0.,NDL(M))
      MA=MMD(2)
      IF (LE.EQ.1) MA=MMD(1)
      Y=YBB(L)+YM(1)
      CALL SYMBOL(X,Y,.1,MA,0.,8)
      Y=YBB(L)+YM(2)
      CALL SYMBOL(X,Y,.1,MMD(4),0.,6)
      X=XBB(L)+XL
      EL=NELEM(LE)
      CALL NUMBER(X,Y,.1,EL,0.,-1)
      X=XBB(L)+XDF
      CALL SYMBOL(X,Y,.1,NFM(LL),0.,1)
      GO TO 130
  100 CALL PLOT(XBB(L),YBB(L),3)
      DO 110 M=1,7
      X=XBB(L)+XBOX(M)
      Y=YBB(L)+YBOX(M)
  110 CALL PLOT(X,Y,2)
      X=XBB(L)+XMA
      XU=XBB(L)+XMU
      DO 120 M=1,8
      MM=M+11
      Y=YBB(L)+YP(M)
      CALL SYMBOL(X,Y,.1,NAM(MM),0.,2)
  120 CALL NUMBER(XU,Y,.1,ENUM(M),0.,NDF(M))
      MA=MMD(3)
      X=XBB(L)+XMA
      Y=YBB(L)+YM(3)
      CALL SYMBOL(X,Y,.1,MA,0.,8)
      Y=YBB(L)+YM(4)
      CALL SYMBOL(X,Y,.1,MMD(4),0.,6)
      X=XBB(L)+XL
      EL=NELEM(LE)
      CALL NUMBER(X,Y,.1,EL,0.,-1)
      X=XBB(L)+XDF
      CALL SYMBOL(X,Y,.1,NFM(LL),0.,1)
  130 CONTINUE
    5 CONTINUE
      IF (SIZE.LE.0.0) GO TO 190
      CALL GARPFT(XG,YG,SIZE)
  190 CALL SYMBOL(XTI,YTI,.14,TITLE,0.,72)
      CALL PLOT(XMOVE,YMOVE,-3)
      RETURN
C
  140 FORMAT (/1X,21-INPUT FOR SUB BOXES -,/13(1X,F7.3)/(1X,4(2F6.3,I3,3 [illegible]
     1X)))
C     END BOXES
      END
```

```
   08/24/78 +CDC CY174 SCOPE VER3.3.4 DATED 09/16/76
09.58.31.B14TTIR
09.58.31.SEQUENCE=B14TT.
09.58.31.ZOO,CM55000,T119.
09.58.31.USER=REYNLDSRS,DEPT=93-352,EWO=3409-2458
09.58.31.39-05-0301,PROGRAM=0.
09.58.32.BANNER,DAYFILE.BIN 27
09.58.32. XXXX   XXX  X   X       XXX  XXXXX
09.58.32. X   X   X   XX  X      X   X     X
09.58.32. X   X   X   XX  X          X    X
09.58.32. XXXX    X   X X X         X    X
09.58.32. X   X   X   X  XX        X    X
09.58.32. X   X   X   X  XX       X    X
09.58.32. XXXX   XXX  X   X      XXXXX X
09.58.32.
09.58.32.
09.58.32.
09.55.32.REQUEST,OLD,PE,VSN=639274,LB=AVDATA,ID=0
09.58.32.EYNOLDS,FILES=49-67.
09.58.32. (OI ASSIGNED)
09.58.32.REWIND(OLD)
09.58.32.COPYBF(OLD,OLD40)
09.58.34.UPDATE(F,P=OLD40,L=1)
09.58.38. UPDATE COMPLETE.
09.58.38.GUF(I,OPT=0,PD=8)
09.59.18.     12.499 CP SECONDS COMPILATION TIME
09.59.18.TOTAL SRU     43.721
09.59.18.TOTAL CP      11.647 SEC.       2.312 SEC.
09.59.18.TOTAL PP      30.770 SEC.
09.59.18.TOTAL IO      11.615 SEC.
09.59.18.TOTAL RA+1 CALLS       566.

                  B14TTIR  //// END OF LIST ////  EST 33
                  B14TTIR  //// END OF LIST ////  EST 33
```

APPENDIX C

LISTING OF 3-D COMBUSTOR PERFORMANCE MODEL


```
      PROGRAM MAIN (INPUT=65,OUTPUT=519,TAPE5=INPUT,TAPE6=OUTPUT,        MA       2
     1 TAPE8,TAPE9,TAPE11=65)                                            MA       3
      COMMON F(500,7),DU(10,10,5),DV(10,10,5),DW(10,10,5),               COMFA    2
     1 RHO(10,10,5),VISC(10,10,5),SU(10,10),SP(10,10),DRHODP(10,10,5),   COMFA    3
     1 AXP(10,10),AXM(10,10),AYP(10,10),AYM(10,10),AZP(10,10),           COMFA    4
     2 AZM(10,10),CZ(10,10),CV(10),CZU(10,10),CVU(10),                   COMFA    5
     3 CZP(10,10),CYP(10),DIVG(10,10),NTP1,NTP2                          COMFA    6
      DIMENSION U(10,10,5),V(10,10,5),W(10,10,5),PP(10,10,5)             COMFA    7
      DIMENSION P(10,10,5),TEMP(10,10,5),GAM(10,10,5)                    COMFA    8
      EQUIVALENCE (F(1,1),U(1,1,1)),(F(1,2),V(1,1,1)),(F(1,3),W(1,1,1))  COMFA    9
      EQUIVALENCE (F(1,4),PP(1,1,1)),(F(1,5),P(1,1,1))                   COMFA   10
      EQUIVALENCE (F(1,6),TEMP(1,1,1)),(F(1,7),GAM(1,1,1))               COMFA   11
      COMMON/CYL/R(30),RM(30),RMV(30),YSR(30),YSVR(30),IPLAX             COMMON   2
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),        COMMON   3
     1 YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),       COMMON   4
     2 FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME                           COMMON   5
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NI,NJ,NK,NINJ,NINJNK,NV,  COMMON   6
     1 NNV,NGOTO,K,ISTR,JSTR,KSTR,NVR(20),KM(30),JM(30),ISTEP,           COMMON   7
     2 ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISWP,JSWP,RELAX(16),NP,    COMMON   8
     3 ARHO,AGAM,IWLI(30,5),IWLO(30,5),JWLO(40,5),JWLI(40,5),IWEI,       COMMON   9
     4 IWEO,NN1,JWII,JWIO,JWOI,JWOO,IDW,JKIN(30,30),IKIN(40,30)          COMMON  10
      COMMON/INDEX/IPAR,LPREF,ISTUM,INCOMP,ITRAD,NVRX,NVRY,NVRZ,JPLANE   COMMON  11
     1 ,PLAXM1,LVK,LVD,LVFUOX,LVFU,LVCO,LVH,LVRX,LVRY,LVRZ,NVF(13),      COMMON  12
     2 IJUMP,IRES,TITLE2(20),IMAX,JMAX,KMAX,NVCO,FUMCO,NVH2O,NVCO2,      COMMON  13
     3 NVN2                                                              COMMON  14
      COMMON/THERM/NVH,NVFU,NVOX,NVFUOX,NVTE,MODEM,IOX,FSTOIC,MFU,CP,    COMMON  15
     1 GASCON,RHOCON,UNICON,PRESS,NVFAV,TCYLW,TINLW,TLIP,ACOEF(4),       COMMON  16
     2 T4,DFAC,WFU,WCO2,WCO,WOX,WH2O,WN2,HVY,CXX,RATIO1,RATIO2,          COMMON  17
     3 RATIO3,RATIO4,HCO,TAN,ITWALL                                      COMMON  18
      COMMON/CTORA/KEWD,ICTORA(13)                                       COMMON  19
      COMMON/MIS/AMU,DEN,SMAX,SSUM,LASTEP,HTCEXT,CFR,EMISW,EMISIN,       COMGEN   2
     1 EMISR,TOUT,BICO,EMI,RADIN,RADSUR,FMA,FK,SDFK,                     COMGEN   3
     2 FKFU,FDFU,TFUEL,WFN2,FLO(40),TENTH(40),H(40),FUEL(40),FUOX(40) ,  COMGEN   4
     3 VIN(40),TIN(40),FUELS(40),SEXIT,IGAM1(10),IGAM2(10)               COMGEN   5
      COMMON/TURB/HVK,AVD,C1,C2,CD,AK,DUIDXJ(3,3),AKFAC,ELFAC,           COMGEN   6
     1 MODEL,PR(13),PREF(13),PJAY(13),E                                  COMGEN   7
      COMMON/RAD/NVE,SIGMA,ABSOR,SCATR                                   COMGEN   8
      COMMON/REACT/ARCON1,PREXP1,CR1,ARCON2,PREXP2,CR2,MODER             COMGEN   9
      COMMON/DROPL/EVAP(192),NTP4,NFNZ,XD(3),YD(3),ZD(3),ALFA(3),        COMGEN  10
     1 BETA(3),DELTA(3),THETA1(3),THETA2(3),NSL(3),WFF(3),SMD(3),        COMGEN  11
     2 VFUEL(3),RFUEL(3),EVSU(64),NEVAP                                  COMGEN  12
      COMMON/INJEC/FLOWIN,IUINJ(20),JUINJ(20),UINJ(20),WUINJ(20),        COMGEN  13
     1 AUINJ(20),TUINJ(20),IVINJ(20),JVINJ(20),KVINJ(20),VINJ(20),       COMGEN  14
     2 EVINJ(20),DVINJ(20),AVINJ(20),TVINJ(20),NUINJ,NVINJ,JSW1,JSW2,    COMGEN  15
     3 USW,VSW,AFSW,FSW,TSW,WSW,SDRO,RHOSW                               COMGEN  16
      DIMENSION CLENO(2),CLENV(2),CENER(2),CMASS(2),CTEMP(2),CPRESS(2)   MA       7
      DIMENSION CANG(2)                                                  MA       8
      DATA CLENO/1.0,.0254/,CLENV/1.0,.3048/,CENER/1.0,1055./            MA       9
      DATA CMASS/1.0,.4536/,CTEMP/1.0,.55555/,CPRESS/1.0,101325./        MA      10
      DATA CANG/1.0,.01745/                                              MA      11
CHAPTER 1 ----------------------PARAMETERS AND CONTROL INDICES--------   MA      12
      NTP1=8                                                             MA      13
      NTP2=9                                                             MA      14
      NTP4=11                                                            MA      15
      READ (5,30) TITLE                                                  MA      16
      READ (5,31) TITLE2                                                 MA      17
   31 FORMAT (20A4)                                                      MA      18
   30 FORMAT (18A4)                                                      MA      19
      READ (5,100) LP1,MP1,NP1,IPLAX,MODEL,MODER,IPAR,ITRAD              MA      20
      READ (5,100) IU,MODEM,INTAPE,IDW,IRES                              MA      21
  100 FORMAT (8(I2,8X))                                                  MA      22
      READ (5,100) ISOLVE                                                MA      23
      READ (5,100) ICTORA                                                MA      24
      READ (5,100) IPRINT                                                MA      25
      READ (5,101) RELAX                                                 MA      26
      READ (5,101) PR                                                    MA      27
      READ (5,101) PREF                                                  MA      28
  101 FORMAT (8E10.4)                                                    MA      29
      PLAXM1=FLOAT(IPLAX-1)                                              MA      30
CHAPTER 2 --------------------------GRID AND GEOMETRY-----------------   MA      31
C-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  MA      32
      CALL STRIDO                                                        MA      33
C-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  MA      34
      READ (5,101) (X(I),I=1,LP1)                                        MA      35
      READ (5,101) (Y(J),J=1,MP1)                                        MA      36
      READ (5,101) (Z(K),K=1,NP1)                                        MA      37
      DO 200 I=1,LP1                                                     MA      38
```

```
  200 X(I)=X(I)*CLENO(IU)
      DO 205 J=1,MP1
  205 Y(J)=Y(J)*CLENO(IU)
      DO 220 K=1,NP1
      GO TO (210,215), IPLAX
  210 Z(K)=Z(K)*CLENO(IU)
      GO TO 220
  215 Z(K)=Z(K)*CANG(IU)
  220 CONTINUE
      RI=Y(1)
      Y(1)=0.0
C  ------  INCLINED WALL DATA
      DO 22 J=1,MP1
      IWLI(J,4)=2
   22 IWLO(J,4)=L
      DO 26 J=1,LP1
      JWLI(J,4)=1
   26 JWLO(J,4)=MP1
      IWEC=L
      JWII=1
      JWOI=1
      JWCO=MP1
      READ (5,100) IWEI,JWIO
      IF (IWEI.EQ.2) GO TO 82
      READ (5,100) (IWLI(J,4),J=JWIO,MP1)
      READ (5,100) (JWLO(I,4),I=1,IWEI)
   82 CONTINUE
      GO TO (23,24),IPAR
24    IREF=L
      JREF=M
      KREF=N
      LPREF=KR(KREF)+JR(JREF)+IREF
23    CONTINUE
      DO 25 J=1,MP1
      GO TO (260,265), IPLAX
  260 R(J)=1.0
      GO TO 25
  265 R(J)=RI+Y(J)
   25 CONTINUE
C*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
      CALL STRI91
C*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
CHAPTER 3 ----------------------DEPENDENT VARIABLES------------------
      READ (5,101) PRESS,DEN,ABSOR,SCATR,AKFAC,ALFAC
      READ (5,101) CII,HTV,HFU,FORCO
      READ (5,101) PREXP1,ARCON1,CR1,PREXP2,ARCON2,CR2
      READ (5,101) C1,C2,CD,AMU,ERROR,TCYLM,TIMLM,ELIP
      READ (5,103) LASTEP,IJUMP,JSW1,JSW2,NUINJ,NVINJ
  103 FORMAT (2(I3,7X),6(I2,8X))
      READ (5,101) USW,VSW,SWNO,AFSW,FSW,TSW
      READ (5,102) NFNZ,ISPRAY,TFUEL
  102 FORMAT (2(I2,8X),6E10.4)
      IF (NFNZ.LE.0) GO TO 110
      DO 115 I=1,NFNZ
      READ (5,101) XO(I),YO(I),ZO(I),ALFA(I),BETA(I),DELTA(I),THETA1(I),
     1   THETA2(I),RNSL,WFF(I),SMD(I),VFUEL(I),RFUEL(I)
  115 NSL(I)=IFIX(RNSL)
      DO 120 II=1,NFNZ
      XO(II)=XO(II)*CLENO(IU)
      YO(II)=YO(II)*CLENO(IU)
      GO TO (125,130), IPLAX
  125 ZO(II)=ZO(II)*CLENO(IU)
      GO TO 135
  130 ZO(II)=ZO(II)*CANG(IU)
  135 ALFA(II)=ALFA(II)*CANG(IU)
      BETA(II)=BETA(II)*CANG(IU)
      DELTA(II)=DELTA(II)*CANG(IU)
      THETA1(II)=THETA1(II)*CANG(IU)
      THETA2(II)=THETA2(II)*CANG(IU)
      WFF(II)=WFF(II)*CMASS(IU)
      RFUEL(II)=RFUEL(II)*CLENO(IU)
  120 VFUEL(II)=VFUEL(II)*CLENO(IU)
  110 CONTINUE
      TFUEL=TFUEL*CTEMP(IU)
      AMU=AMU*CMASS(IU)/CLENV(IU)
      PRESS=PRESS*CPRESS(IU)
      DEN=DEN*CMASS(IU)/CLENO(IU)/CLENO(IU)/CLENO(IU)
```

```
      TCYLW=TCYLW*CTEMP(IU)
      TINLW=TINLW*CTEMP(IU)
      TLIP=TLIP*CTEMP(IU)
      USB=USB*CLENV(IU)
      VSW=VSW*CLENV(IU)
      AFSW=AFSW*CMASS(IU)
      FSW=FSW*CMASS(IU)
      TSW=TSW*CTEMP(IU)
      IF (NUINJ.LE.0) GO TO 85
      READ (5,100) (IUINJ(I),I=1,NUINJ)
      READ (5,100) (JUINJ(I),I=1,NUINJ)
      READ (5,101) (UINJ(I),I=1,NUINJ)
      READ (5,101) (WUINJ(I),I=1,NUINJ)
      READ (5,101) (AUINJ(I),I=1,NUINJ)
      READ (5,101) (TUINJ(I),I=1,NUINJ)
      DO 235 II=1,NUINJ
      UINJ(II)=UINJ(II)*CLENV(IU)
      WUINJ(II)=WUINJ(II)*CLENV(IU)
      AUINJ(II)=AUINJ(II)*CMASS(IU)
  235 TUINJ(II)=TUINJ(II)*CTEMP(IU)
   85 IF (NVINJ.LE.0) GO TO 88
      READ (5,100) (IVINJ(I),I=1,NVINJ)
      READ (5,100) (JVINJ(I),I=1,NVINJ)
      READ (5,100) (KVINJ(I),I=1,NVINJ)
      READ (5,101) (VINJ(I),I=1,NVINJ)
      READ (5,101) (EVINJ(I),I=1,NVINJ)
      READ (5,101) (DVINJ(I),I=1,NVINJ)
      READ (5,101) (AVINJ(I),I=1,NVINJ)
      READ (5,101) (TVINJ(I),I=1,NVINJ)
      DO 240 II=1,NVINJ
      VINJ(II)=VINJ(II)*CLENV(IU)
      EVINJ(II)=EVINJ(II)*CLENV(IU)*CLENV(IU)
      DVINJ(II)=DVINJ(II)*CLENV(IU)
      AVINJ(II)=AVINJ(II)*CMASS(IU)
  240 TVINJ(II)=TVINJ(II)*CTEMP(IU)
   88 CONTINUE
      WFU=12.*CXX+HYY
      ISTEP=IRES
      DFAC=1.0
      SUM1=.01
      SUM2=.05
CHAPTER 4 -------------------MATERIAL CONSTANTS--------------------------
      PREF(LVD)=AF*AK/(C2-C1)/SQRT(CD)
      DO 93 NV=1,NNV
      PRRAT=PR(NV)/PREF(NV)
   93 PJAY(NV)=E*(PRRAT-1.)/PRRAT**.25
      RHOCON=PRESS/UNICON
      GASCON=UNICON/WM2
CHAPTER 5 ------------------------INITIAL VALUES-------------------------
      CALL START
      CALL OUTPUT (INTAPE)
C------------- MAIN LOOP STARTS -------------------------------------------
60    CONTINUE
C+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
      IF (ISTEP.EQ.100) ISOLVE(LVK)=9
      IF (ISTEP.EQ.100) ISOLVE(LVD)=9
      CALL DENS
      ISP=ISPRAY
      IF (ISTEP-IRES.LE.5) ISP=1
      IF (MOD(ISTEP-IRES,ISP).EQ.0) CALL SPRAY
      CALL VISC3
C+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
CHAPTER 6 -------------------SINGLE LINE PRINTOUT----------------------
      IF (ISTEP.EQ.IRES) GO TO 16
      WRITE (6,10) ISTEP,SMAX,SSUM,SEFIT,P(2,M,2),P(L,M,2),
     1  U(IMAX,JMAX,KMAX),V(IMAX,JMAX,KMAX),W(IMAX,JMAX,KMAX),
     2  TEMP(IMAX,JMAX,KMAX),RHO(IMAX,JMAX,KMAX),IMAX,JMAX,KMAX
   10 FORMAT (1X,I4,10(1PE11.3),1X,3I3)
   16 CONTINUE
C+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
      CALL STRID2
C+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
CHAPTER 7 ------------------------OUTPUT---------------------------------
      IF (ERROR.GT.SSUM) ISTEP=LASTEP
      DFAC=AMAX1(0.,(SUM2-SSUM)/(SUM2-SUM1))
      DFAC=AMIN1(1.0,DFAC)
      CALL OUTPUT (NTP1)
```

```
PROGRAM MAIN        73/74    OPT=0 TRACE                    FTN 4.6+439       05/24/79  14.05.45        PAGE     [illegible]

              CHAPTER 8  ------------------TERMINATION ---------------------------    MA        193
                  IF (ISTEP-LASTEP) 60,80,90                                          MA        194
                80 WRITE (6,10) ISTEP,SMAX,SSUM                                       MA        195
 235          C +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+       MA        196
                  STOP                                                                MA        197
                  END                                                                 MA        198

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

   81       I                 CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
   82       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
  103       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
  112       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
  128       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
  198       I                 CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
```

```
      BLOCK DATA                                                        MA        199
      COMMON/CYL/R(30),RD(30),RH(30),TS(30),TSW(30),IPLAE               COMMON      2
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSD(40),       COMMON      3
     1  YSW(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),     COMMON      4
     2  FYP(30),FYM(30),FZP(30),FZM(30),CT,TIME                         COMMON      5
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NI,NJ,NK,NIMJ,NIMJNK,NV, COMMON      6
     1  NNV,NGGTJ,K,ISTR,JSTR,KSTR,NVN(20),KM(30),JM(30),ISTEP,         COMMON      7
     2  ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISYM,JSYM,RELAX(13),MP,  COMMON      8
     3  NRHO,NGAM,IWLI(30,5),IWLO(30,5),JWLO(40,5),JWLI(40,5),IWEI,     COMMON      9
     4  IWED,NW1,JWII,JWI3,JWOI,JW30,IDW,JKIM(30,30),IKIM(40,30)        COMMON     10
      COMMON/INDEX/IPAX,LPREF,ISTUM,INCOMP,ITRAD,NVRX,NVRY,NVRZ,JPLANE  COMMON     11
     1  ,PLANE1,LVK,LVD,LVFUOX,LVFU,LVCO,LVM,LVRX,LVRY,LVRZ,NVF(13),    COMMON     12
     2  IJUMP,IRES,TITLE2(20),IMAX,JMAX,KMAX,NVCO,FUMCO,NVH2O,NVCO2,    COMMON     13
     3  NVN2                                                            COMMON     14
      COMMON/THERM/NVH,NVFU,NVOX,NVFUOX,NVTE,MODEL,IDM,FSTOIC,MFU,CP,   COMMON     15
     1  GASCON,RHOCON,VMICON,PRESS,NVFAV,TCVLW,TIMLW,TLIP,ACOEF(4),     COMMON     16
     2  T4,DFAC,WFU,WCO2,WCG,WOX,WH2O,WN2,NVT,CKT,RATIO1,RATIO2,        COMMON     17
     3  RATIO3,RATIO4,KC7,TAM,TWALL                                     COMMON     18
      COMMON/CTOMA/KEMO,ICTOMA(13)                                      COMMON     19
      COMMON/MIS/AMU,DEN,SMAX,SSUM,LASTEP,MITEXT,CER,EMISW,EMISIN,      CONGEN      2
     1  ENTSE,TOGT,ETCS,ENT,RADIN,RADSUM,FMA,FE,SEFF,                   CONGEN      3
     2  FXFU,FOFU,TFUEL,WFMZ,FLD(40),TEMIN(40),  (40),FUEL(40),FUOX(40) ,CONGEN     4
     3  UIN(40),TIN(40),FUELS(40),SEXIT,IGAM1(13),IGAM2(10)             CONGEN      5
      COMMON/TURB/NVK,NVD,C1,C2,CD,AK,DUIDX(3,3)-AKFAC,ALFAC,           CONGEN      6
     1  MODEL,PR(13),PREF(13),PJAT(13),E                                CONGEN      7
      COMMON/RAD/NVE,SIGMA,ABSOR,SCATR                                  CONGEN      8
      COMMON/REACT/ARCOM1,PREXP1,CR1,ARCOM2,   ,P2,CR2,MODER            CONGEN      9
      COMMON/DROPL/EVAP(132),NTP6,NFMZ,XC(3),YC(3),ZC(3),ALFA(3),       CONGEN     10
     1  BETA(3),DELTA(3),THETA1(3),THETA2(3),WSL(3),WF(3),SMD(3),       CONGEN     11
     2  VFUEL(3),PFUEL(3),EVSU(64),NEVAP                                CONGEN     12
      COMMON/INJEC/FLOWIN,IUINJ(20),JUINJ(20),UINJ(20),GUINJ(20),       CONGEN     13
     1  AUINJ(20),TUINJ(20),IVINJ(20),JVINJ(20),GVINJ(20),VINJ(20),     CONGEN     14
     2  EVINJ(20),DVINJ(20),AVINJ(20),TVINJ(20),MUINJ,MVINJ,JSW1,JSW2,  CONGEN     15
     3  USW,VSW,AFSW,FSW,TSW,WSW,SWND,RHOSW                             CONGEN     16
      DATA NI,NJ,NK,NNV/10,10,5,10/                                     MA        202
      DATA AK,E/.43,9./                                                 MA        203
      DATA GASCON,SIGMA/8314.,5.668E-08/                                MA        204
      DATA NVK,NVD,NVFUOX,NVFU,NVCG,NVTE,NVH/4,5,4,5,8,6,9/             MA        205
      DATA NVFAV,NVRX,NVRY,NVRZ/10,1,2,3/                               MA        206
      DATA NVF/1,2,3,4,4,5,4,5,8,9,1,2,3/                               MA        207
      DATA LVK,LVD,LVFUOX,LVFU,LVCG,LVH/5,6,7,8,9,10/                   MA        208
      DATA LVRX,LVRY,LVRZ/11,12,13/                                     MA        209
      DATA NVH2O,NVOX,NVCO2,NVN2/1,2,3,4/                               MA        210
      DATA MP,NRHO,NGAM/14,15,16/                                       MA        211
      DATA WCO2,WCO,WOX,WH2O,WN2/44.,28.,32.,18.,28./                   MA        212
      DATA IGAM1,IGAM2/1,0,1,1,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0,0/         MA        213
      DATA ACOEF/-1306.01,8420.37,-6167.08,1336.65/                     MA        214
      END                                                               MA        215
```

```
      SUBROUTINE INITIAL
      COMMON F(500,7),DU(10,10,5),DV(10,10,5),DW(10,10,5),
     1 RHO(10,10,5),VISC(10,10,5),SU(10,10),SP(10,10),DRHODP(10,10,5),
     1 AXP(10,10),AXM(10,10),AYP(10,10),AYM(10,10),AZP(10,10),
     2 AZM(10,10),CZ(10,10),CY(10),CZU(10,10),CYU(10),
     3 CZP(10,10),CYP(10),DIVG(10,10),NTP1,NTP2
      DIMENSION U(10,10,5),V(10,10,5),W(10,10,5),PP(10,10,5)
      DIMENSION P(10,10,5),TEMP(10,10,5),GAM(10,10,5)
      EQUIVALENCE (F(1,1),U(1,1,1)),(F(1,2),V(1,1,1)),(F(1,3),W(1,1,1))
      EQUIVALENCE (F(1,4),PP(1,1,1)),(F(1,5),P(1,1,1))
      EQUIVALENCE (F(1,6),TEMP(1,1,1)),(F(1,7),GAM(1,1,1))
      COMMON/CYL/R(30),RM(30),RMV(30),YSR(30),YSVR(30),IPLAX
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),
     1 YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),
     2 FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NI,NJ,NK,NIJ,NIJNK,NV,
     1 NNT,NGOTO,K,ISTR,JSTR,KSTR,NTM(20),KM(30),JM(30),ISTEP,
     2 ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISUP,JSUP,RELAX(16),NP,
     3 NRHO,NGAM,IWLI(30,5),IWLO(30,5),JWLG(40,5),JWLI(40,5),IWSI,
     4 IWSO,MM1,JWII,JWIO,JWOI,JWOO,IOW,JKIN(30,30),IKIN(40,30)
      COMMON/INDEX/IPAR,IPREF,ISTUM,INCOMP,ITRAD,NVRX,NVRY,NVRZ,JPLANE
     1 ,PLAXM1,LFK,LVD,LVFUOX,LVFU,LVCO,LVM,LVRX,LVRY,LVRZ,NVF(13),
     2 IJUMP,IRES,TITLE2(20),IMAX,JMAX,KMAX,NVCO,FOMCO,NVH2O,NVCO2,
     3 NVN2
      COMMON/THERM/NUM,NVFU,NVOX,NVFUOX,NVTE,MODEN,IDK,FSTOIC,HFU,CP,
     1 GASCON,RHOCON,VNICON,PRESS,NVFAV,TCYLW,TINLW,TLIP,ACOEF(4),
     2 T4,DFAC,WFU,WCO2,WCO,WOX,WH2O,WN2,HYY,CXX,RATIO1,RATIO2,
     3 RATIO3,RATIO4,HCO,TAN,ITWALL
      COMMON/CTOMA/KEND,ICTOMA(13)
      COMMON/MIS/AMU,DEN,SMAX,SSUM,LASTEP,HTCEXT,CFR,EMISW,EMISIN,
     1 EMISR,TOUT,RTCD,ENL,RADIN,RADSUR,FMA,FK,SQFK,
     2 FKFU,FDFU,TFUEL,WFRZ,FLD(40),TEMTH(40),H(40),FUEL(40),FUOX(40) ,
     3 UIN(40),TIN(40),FUELS(40),SEXIT,IGAM1(10),IGAM2(10)
      COMMON/TURB/NVK,NVD,C1,C2,CD,AK,DUIDXJ(3,3),AKFAC,ALFAC,
     1 MODEL,PR(13),PREF(13),PJAY(13),E
      COMMON/RAD/NVE,SIGMA,ABSOR,SCATR
      COMMON/REACT/ARCON1,PREXP1,CR1,ARCON2,PREXP2,CR2,MODER
      COMMON/DROPL/EVAP(192),NTP6,NFNZ,XD(3),YD(3),ZD(3),ALFA(3),
     1 BETA(3),DELTA(3),THETA1(3),THETA2(3),NSL(3),WFF(3),SMD(3),
     2 VFUEL(3),RFUEL(3),EVSU(64),NEVAP
      COMMON/INJEC/FLOWIN,IUINJ(20),JUINJ(20),UINJ(20),WUINJ(20),
     1 AUINJ(20),TUINJ(20),IVINJ(20),JVINJ(20),KVINJ(20),VINJ(20),
     2 EVINJ(20),DVINJ(20),AVINJ(20),TVINJ(20),NUINJ,NVINJ,JSW1,JSW2,
     3 USW,VSW,AFSW,FSW,TSW,WSW,SWNO,RHOSW
      DIMENSION A(40)
C  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **
      ENTRY START
C ------------- SOME PRELIMINARY VALUES -------------------------
      HCO=1.0112E+7
      RATIO1=WOX*(CXX+HYY/4.)/WFU
      RATIO2=.232
      RATIO3=WCX*0.5/WCO
      RATIO4=WCO*CXX/WFU
      FSTOIC=RATIO2/(RATIO1+RATIO2)
      A(1)=COEF(WFU,1)
      A(1)=COEF(HFU,1)
      CFR=.003
      EMISW=.8
      EMISIN=1.
      EMISR=1.
      UMASS=0.
      SMASS=1.E-30
      ASW=AFSW-FSW
      FUMSW=FSW/AFSW
      FUOXSW=FUMSW
      WSW=SWNO*USW
      UMASS=AFSW*USW
      SMASS=AFSW
      FK=AMAX1(0.,AKFAC*(UMASS/SMASS)**2)*FLOAT(MODEL-1)
      SQFK=SQRT(FK)
      ASWRLR=0.
      DO 10 J=JSW1,JSW2
   10 ASWRLR=ASWRLR+YSR(J)*(Z(NP1)-Z(1))
      ALIN=.5*ALFAC*(Y(JSW2)+Y(JSW2+1)-Y(JSW1)+Y(JSW1-1))
      RHOSW=AFSW/ASWRLR/USW
      RTCD=SQRT(CD)
      DO 40 I=1,LPI
```

```
   40 FUELS(I)=0.
      IF (NFMZ.LE.0) GO TO 48
      DO 165 II=1,NFMZ
      DO 165 I=2,L
      IF (XDC(II).GT.0.5*(X(I)+X(I+1))) GO TO 165
      FUELS(I)=FUELS(I)+WFF(II)
  165 CONTINUE
   48 FUELS(LP1)=FUELS(L)
      WFMZ=FUELS(LP1)
      DO 88 K=1,MP1
      DO 82 J=1,MP1
   82 JWIM(J,K)=0
      DO 80 I=1,LP1
   85 IXIM(I,K)=0
      DO 86 K=1,MP1
      DO 86 J=JS+1,JS+2
   86 JWIM(J,K)=1
   84 CONTINUE
   88 IF (NVINJ.LE.0) GO TO 92
      DO 94 II=1,NVINJ
      I=IVINJ(II)
      J=JVINJ(II)
      K=KVINJ(II)
      IF (J.EQ.JWL(I,K)) GO TO 96
      IXIM(I,K)=IXIM(I,K)+2
      GO TO 94
   96 IXIM(I,K)=IXIM(I,K)+1
   94 CONTINUE
   92 IF (NUINJ.LE.0) GO TO 190
      DO 190 II=1,NUINJ
      I=IUINJ(II)-1
      J=JUINJ(II)
      IF (J.EQ.JWL(I,K)+1) GO TO 197
      DO 196 K=1,MP1
  196 IXIM(I,K)=IXIM(I,K)+2
      GO TO 198
  197 DO 195 K=1,MP1
  195 IXIM(I,K)=IXIM(I,K)+1
  198 CONTINUE
  190 CONTINUE
C ------ COMPUTE TOTAL FLOW RATE  --------------------------
   34 DO 499 I=1,LP1
      FLO(I)=0.
      FUEL(I)=0.
  499 TEMTM(I)=0.
      FLO(I)=AFSW
      FUEL(I)=FSW
      TEMTM(I)=AFSW*TSW
C ------ AXIAL INJECTION
      IF (NUINJ.LE.0) GO TO 104
      DO 106 II=1,NUINJ
      I=IUINJ(II)-1
      FLO(I)=FLO(I)+AUINJ(II)
  106 TEMTM(I)=TEMTM(I)+TUINJ(II)*AUINJ(II)
C ------ RADIAL INJECTION
  104 IF (NVINJ.LE.0) GO TO 108
      DO 110 II=1,NVINJ
      I=IVINJ(II)
      FLO(I)=FLO(I)+AVINJ(II)
  110 TEMTM(I)=TEMTM(I)+TVINJ(II)*AVINJ(II)
  108 CONTINUE
C ------ FLOW RATE AT EACH I-STATION
      DO 135 I=2,LP1
      FLO(I)=FLO(I-1)+FLO(I)
      FUEL(I)=FUEL(I-1)+FUEL(I)
  135 TEMTM(I)=TEMTM(I-1)+TEMTM(I)
      FLOWIN=FLO(LP1)+WFMZ
      DO 145 I=1,LP1
  145 FUOX(I)=FUEL(I)/FLO(I)
      FUTOT=FUEL(LP1)+WFMZ
      AMASS=FLO(LP1)-FUEL(LP1)
      FUARAT=FUTOT/AMASS
      DO 150 I=1,LP1
      FUELI=(FUEL(I)+FUELS(I))/(FLO(I)+FUELS(I))
      FUELF=AMAX1(FUELI-RATIO2*(1.-FUELI)/RATIO1,0.)
      PHI=FUELI/FSTOIC
      WI=FUELI*WGR(TSW,1)+(1.-FUELI)*RATIO2*WGR(TSW,4)+(1.-FUELI)*
```

```
      1  (1.-RATIO2)*HOR(TSW,12)
         TIN(1)=TSW
         FUB=FUELI-FUELF
         FLPCO2=WCO2*CXX*FUB/WFU-WCO2*FUNCO/WCO
         FLPOX=RATIO1*FUELF+RATIO3*FUNCO+RATIO2-(RATIO1+RATIO2)*FUELI
         FLPOX=AMAX1(FLPOX,0.)
         FLPH2O=HYY*WH2O*FUB/WFU/2.
         FLPN2=1.-FUELF-FLPCO2-FUNCO-FLPOX-FLPH2O
         DO 151 II=1,10
         T=TIN(I)
         H2=FUELF*HOR(T,1)+FLPCO2*HOR(T,2)+FUNCO*HOR(T,3)+
      1     FLPOX*HOR(T,4)+FLPH2O*HOR(T,5)+FLPN2*HOR(T,12)
         CPI=FUELF*CPOR(T,1)+FLPCO2*CPOR(T,2)+FUNCO*CPOR(T,3)+
      1     FLPOX*CPOR(T,4)+FLPH2O*CPOR(T,5)+FLPN2*CPOR(T,12)
         TNEW=T+(H1-H2)/CPI
         TMAX=ACOEF(1)+PHI*(ACOEF(2)+PHI*(ACOEF(3)+PHI*ACOEF(4)))
         TMAX=AMAX1(TMAX,2000.)
         TNEW=AMIN1(TNEW,TMAX)
         IF (ABS(TIN(I)-TNEW).LT.10.) GO TO 150
  151    TIN(I)=TNEW
         WRITE (6,156)
  156    FORMAT ('   **ERROR-1**')
  150    CONTINUE
         T4=TIN(LP1)
         CP=RATIO2*CPOR(T4,4)+(1.-RATIO2)*CPOR(T4,12)
         DO 231 I=3,LP1
         J1=IMAX(I-1)
         J2=IMIN(I,1)
         RHO4=PRESS/GASCON/TIN(I-1)
         A4=.5*(Z(NP1)-Z(1))*(RM(J2)**2-RM(J1+1)**2)
         IF (IPLAX.EQ.2) GO TO 231
         Y1=.5*(Y(J1)+Y(J1+1))
         IF (J1.EQ.1) Y1=Y(J1)
         Y2=.5*(Y(J2)+Y(J2-1))
         IF (J2.EQ.NP1) Y2=Y(J2)
         A4=(Z(NP1)-Z(1))*(Y2-Y1)
  231    UIN(I)=FLD(I-1)/RHO4/A4
         EMI=EMISW/(2.-EMISW)
         RADIN=EMISIN*SIGMA*TSW**4
         RADSUR=EMISR*SIGMA*T4**4
C ---------      PRINTOUT INPUT DATA     ----------------------------------
         WRITE (6,1004) TITLE2
 1004    FORMAT (/25X,20A4/25X,80(1H-)/)
         HCRAT=HYY/CXX
         WRITE (6,2010) HCRAT,WFU,HFU
 2010    FORMAT (2X,'I.     PHYSICAL INPUT'/8X,14(1H-)/10X,'1.FUEL-'/
      4    30X,'HYDROGEN-CARBON RATIO -----------',1PE12.4,/
      2    30X,'MOLECULAR WEIGHT--------------------',1PE12.4,'  (KG/KGMOLE)'/
      3    30X,'HEAT OF FORMATION-------------------',1PE12.4,'  (CAL/GMOLE)')
         JJ=1
         WRITE (6,2014) JJ,FSW
 2014    FORMAT (30X,'INLET-',I1,' MASS FLOW RATE-----------',1PE12.4,
      1  '   (KG/S)')
         WRITE (6,2020) PRESS
 2020    FORMAT (10X,'2.AIR -'/
      3    30X,'PRESSURE------------------------------',1PE12.4,'  (NEW/SQ.M)')
         WRITE (6,2024) JJ,ASW,JJ,USW,JJ,SWNO
 2024    FORMAT (30X,'INLET-',I1,' MASS FLOW RATE------------',1PE12.4,
      1  '   (KG/S)'/30X,'INLET-',I1,' AXIAL VELOCITY-------------',1PE12.4,
      2  '   (M/S)'/30X,'INLET-',I1,' SWIRL NUMBER--------------',
      3    1PE12.4)
         HEIGHT=2.*(Y(NP1)-Y(1))
         ALNGHT=X(LP1)-X(1)
         SECTOR=Z(NP1)-Z(1)
         WRITE (6,2025) HEIGHT,ALNGHT,SECTOR
 2025    FORMAT (2X,'II.    GEOMETRICAL INPUT'/8X,18(1H-)/
      1    30X,'CHANNEL HEIGHT OF COMBUSTOR-------',1PE12.4,'  (M)'/
      2    30X,'LENGTH OF COMBUSTOR-----------------',1PE12.4,'  (M)'/
      2    30X,'ANGULAR SECTOR----------------------',1PE12.4,'  (RAD-M)')
         WRITE (6,2029) JJ,ASWRLP
 2029    FORMAT (30X,'INLET-',I1,' FLOW AREA-----------------',1PE12.4,
      1  '   (SQ.M)')
         IF (NUINJ+NVINJ+NFNZ.GT.0) WRITE (6,2030)
 2030    FORMAT (2X,'III.  AIR INJECTIONS'/8X,14(1H-))
         IF (NUINJ.LE.0) GO TO 770
         WRITE (6,2031)
 2031    FORMAT (15X,'1.FILM COOLING AIR-')
```

```
      WRITE (6,2033)
 2033 FORMAT (25X,'SLOT NO',4X,'I',5X,'J',6X,'K',8X,'U-VELOCITY',
     1  5X,'V-VELOCITY',5X,'W-VELOCITY',6X,'MASS FLOW',6X,'FUEL FLOW'/
     2  59X,'(M/S)',10X,'(M/S)',10X,'(M/S)',10X,'(KG/S)',9X,'(KG/S)')
      DO 772 II=1,NUINJ
      I=IUINJ(II)
      J=JUINJ(II)
  772 WRITE (6,2090) II,I,J,KUDEF,UINJ(II),UDEF,WUINJ(II),AUINJ(II)
  770 IF (NVINJ.LE.0) GO TO 774
      WRITE (6,2034)
 2034 FORMAT (/10X,'2.DILUTION AND SECONDARY AIR-')
      WRITE (6,2033)
      DO 776 II=1,NVINJ
      I=IVINJ(II)
      K=KVINJ(II)
      J=JVINJ(II)
  776 WRITE (6,2090) II,I,J,K,UDEF,VINJ(II),UDEF,AVINJ(II)
  774 CONTINUE
 2090 FORMAT (27X,I3,4X,I3,3X,I3,2X,I3,8X,1PE10.3,4(5X,1PE10.3))
  810 IF (NFNZ.LE.0) GO TO 813
      WRITE (6,816)
  816 FORMAT (/10X,'3.FUEL NOZZLES-'/12X,'XO',8X,'YO',8X,'ZO',6X,'ALFA',
     1  6X,'BETA',5X,'DELTA',4X,'THETA1',4X,'THETA2',7X,'NSL',8X,'WF',
     2  7X,'SMD',5X,'VFUEL'/11X,'(M)',7X,'(M)',6X,'(M-R)',4X,'(RAD)',
     3  5X,'(RAD)',5X,'(RAD)',5X,'(RAD)',5X,'(RAD)',8X,'-',6X,'(KG/S)',
     4  3X,'(MICRON)',2X,'(M/S)')
      DO 818 I=1,NFNZ
      RNSL=FLOAT(NSL(I))
  818 WRITE (6,819) XO(I),YO(I),ZO(I),ALFA(I),BETA(I),DELTA(I),
     1  THETA1(I),THETA2(I),RNSL,WFF(I),SMD(I),VFUEL(I)
  819 FORMAT (5X,1P12E10.2)
  813 CONTINUE
      WRITE (6,2037) FUTOT,AMASS,FUARAT
 2037 FORMAT (/2X,'IV.   AIR-FUEL BALANCE'/8X,16(1H-)/
     1  30X,'TOTAL FUEL FLOW RATE-------------',1PE12.4,'  (KG/S)'/
     2  30X,'TOTAL AIR FLOW RATE--------------',1PE12.4,'  (KG/S)'/
     3  30X,'FUEL TO AIR RATIO----------------',1PE12.4,/)
      WRITE (6,2040) CP,ARCON1,PREXP1,CR1,ARCON2,PREXP2,CR2,
     1  C1,C2,CD,ABSOR,SCATR
 2040 FORMAT (2X,'V.    SOME IMPORTANT QUANTITIES'/8X,24(1H-)/
     1  30X,'SPECIFIC HEAT--------------------',1PE12.4,'  (J/KG-K)'/
     2  30X,'ACTIVATION ENERGY (1ST) ---------',1PE12.4,'  (K)'/
     3  30X,'PRE-EXPONENT (1ST) --------------',1PE12.4,/
     3  30X,'EDDY BREAKUP CONSTANT (1ST) -----',1PE12.4,/
     7  30X,'ACTIVATION ENERGY (2ND) ---------',1PE12.4,'  (K)'/
     8  30X,'PRE-EXPONENT (2ND) --------------',1PE12.4,/
     9  30X,'EDDY BREAKUP CONSTANT (2ND) -----',1PE12.4,/
     4  30X,'TURB. CONSTANT (C1) -------------',1PE12.4,/
     4  30X,'TURB. CONSTANT (C2) -------------',1PE12.4,/
     4  30X,'TURB. CONSTANT (CD) -------------',1PE12.4,/
     5  30X,'ABSORPTION COEFFICIENT-----------',1PE12.4,/
     6  30X,'SCATTERING COEFFICIENT-----------',1PE12.4,/)
      WRITE (6,2042) (RELAX(I),I=1,16)
 2042 FORMAT (/8X,'RELAXATION PARAMETERS'/8X,21(1H-)/(5X,1P10E12.3))
      GO TO (2050,2051), MODEL
 2050 WRITE (6,2052) (PR(I),I=1,13)
      GO TO 2053
 2051 WRITE (6,2052) (PREF(I),I=1,13)
 2052 FORMAT (/8X,'PRANDTL NUMBERS'/8X,15(1H-)/(5X,1P10E12.3))
 2053 CONTINUE
      WRITE (6,2044) (X(I),I=1,LP1)
 2044 FORMAT (/8X,'X-COORDINATES'/8X,13(1H-)/(5X,1P10E12.3))
      WRITE (6,2046) R(1),(Y(J),J=2,MP1)
 2046 FORMAT (/8X,'Y-COORDINATES'/8X,13(1H-)/(5X,1P10E12.3))
      WRITE (6,2048) (Z(K),K=1,NP1)
 2048 FORMAT (/8X,'Z-COORDINATES'/8X,13(1H-)/(5X,1P10E12.3))
C +-+-+-+-+-+-+-+-+-   CREATE INITIAL DATA TAPE   +-+-+-+-+-+-+-+-+-+-
C ---------    RESTART OPTIONS
      IF (IRES.EQ.0) GO TO 201
      REWIND NTP1
      DO 202 II=1,2
  202 READ (NTP1)
C ------- HERE PP IS PHI, P IS MFU, DU IS MCO
      READ (NTP1) PP,P,DU
C ------- HERE DV IS ENTHALPY, DW IS FAV
      READ (NTP1) DV,DW
C-------- HERE U IS FX, V IS FY, W IS FZ
```

```
      READ (NTP1) U,V,W
      READ (NTP1) TEMP,RHO
      RETURN
C ---------- ZERO ARRAYS
  201 DO 204 NV=1,12
      DO 204 K=1,NP1
      DO 204 J=1,MP1
      KJM=KM(K)+JM(J)
      DO 204 I=1,LP1
      LP=KJM+I
  204 F(LP,NV)=0.
C +-+-+-+-+-+-+-+-+-+-  U,V,W AND PRESSURE  -+-+-+-+-+-+-+-+-+-+-+
      DO 451 K=1,NP1
      DO 451 J=2,M
      IS=IWLI(J,4)
      IE=IWLO(J,4)
      DO 451 I=IS,IE
      IF (I.EQ.IS) GO TO 452
      U(I,J,K)=UIN(I)
  452 W(I,J,K)=.001
      IF (J.EQ.JWLI(I,4)+1) GO TO 451
      V(I,J,K)=.001
  451 CONTINUE
      IF (IPAR.EQ.2) GO TO 255
      DO 209 K=1,NP1
      DO 209 J=1,MP1
      IS=IWLI(J,5)
      IE=IWLO(J,5)
      DO 209 I=IS,IE
  209 P(I,J,K)=PRESS
C ---------- BOUNDRY NODES
  255 DO 240 K=1,NP1
      IF (IDW.EQ.1) GO TO 241
      DO 242 I=3,LPI
      J=JWLI(I,4)
      U(I,J,K)=UIN(I)
  242 CONTINUE
  241 CONTINUE
      DO 244 J=JSW1,JSW2
      I=IWLI(J,4)-1
      U(I+1,J,K)=USW
      V(I,J,K)=VSW
  244 V(I,J+1,K)=VSW
  247 CONTINUE
      DO 245 J=1,MP1
      I=IWLO(J,4)+1
      IF (J.LE.JWOI.OR.J.GE.JWOO) GO TO 245
      U(I,J,K)=U(I-1,J,K)
  245 CONTINUE
C ---------- INJECTION POINTS
      IF (NUINJ.LE.0) GO TO 240
      DO 246 II=1,NUINJ
      I=IUINJ(II)
      J=JUINJ(II)
      U(I,J,K)=UINJ(II)
      U(I-1,J,K)=0.
  246 W(I-1,J,K)=WUINJ(II)
  240 CONTINUE
      IF (NVINJ.LE.0) GO TO 249
      DO 250 II=1,NVINJ
      I=IVINJ(II)
      J=JVINJ(II)
      K=KVINJ(II)
      V(I,J,K)=VINJ(II)
      IF (J.EQ.JWLI(I,4)) V(I,J+1,K)=VINJ(II)
  250 CONTINUE
  249 CONTINUE
      REWIND NTP1
      WRITE (NTP1) U,V,W,P
C +-+-+-+-+-+-+-  TURBULENT KINETIC ENERGY AND DISSIPATION  -+-+-+-+-+-+-+
      DO 437 K=1,NP1
      DO 419 J=1,MP1
      KJM=KM(K)+JM(J)
      IS=IWLI(J,5)
      IE=IWLO(J,5)
      DO 419 I=IS,IE
      LP=KJM+I
```

```
      F(LP,NVK)=FK
      DY=Y(JWLO(I,4))-Y(J)
      IF (IDW.EQ.1) DY=AMIN1(Y(JWLO(I,4))-Y(J),Y(J)-Y(JWLI(I,4)))
      DY=AMAX1(DY,C.)
      AL=ALFAC*DY
  418 F(LP,NVD)=CD*FK**1.5/(AL+1.E-30)
      DO 775 J=JSW1,JSW2
      LP=KM(K)+JM(J)+IWLI(J,4)-1
  775 F(LP,NVD)=CD*FK**1.5/ALIN
      IF (NUINJ.LE.0) GO TO 437
      DO 270 II=1,NUINJ
      I=IUINJ(II)-1
      J=JUINJ(II)
      LP=KM(K)+JM(J)+I
      F(LP,NVK)=AKFAC*(UINJ(II)**2+WUIMJ(II)**2)
      AL=ALFAC*YS(J)
  270 F(LP,NVD)=CD*F(LP,NVK)**1.5/(AL+1.E-30)
  437 CONTINUE
      IF (NVINJ.LE.0) GO TO 272
      DO 274 II=1,NVINJ
      I=IVINJ(II)
      J=JVINJ(II)
      K=KVINJ(II)
      LP=KM(K)+JM(J)+I
      F(LP,NVK)=EVINJ(II)
  274 F(LP,NVD)=CD*F(LP,NVK)**1.5/(DVINJ(II)+1.E-30)
  272 CONTINUE
C ------- HERE PP IS KE, P IS DISSIPATION
      WRITE (NT*1) PP,P
C +-+-+-+-+-+-+-+-+-+-+-+- PHI,FUEL,CO AND TEMP -+-+-+-+-+-+-+-+-+-+-+-+-+
      DO 404 K=1,MP1
      DO 404 J=1,MP1
      KJM=KM(K)+JM(J)
      IS=IWLI(J,5)
      IE=IWLO(J,5)
      DO 406 I=IS,IE
      LP=KJM+I
  406 F(LP,NVTE)=TIN(I)
      IS=IWLI(J,4)
      IE=IWLO(J,4)
      DO 404 I=IS,IE
      LP=KJM+I
      F(LP,NVFUOX)=FUOX(I)
      F(LP,NVFU)=AMAX1(0.,F(LP,NVFUOX)-RATIO2*(1.-F(LP,NVFUOX))/RATIO1)
  404 F(LP,NVCO)=FUMCO
C ------BOUNDRY NODES
      DO 495 K=1,NP1
      DO 206 I=1,LP1
      J=JWLI(I,4)
      LP=KM(K)+JM(J)+I
      IF (IDW.EQ.0) GO TO 217
      TEMP(I,J,K)=TCYLW
      IF (J.EQ.1) GO TO 208
      TEMP(I,J,K)=TINLW
  208 F(LP,NVFUOX)=0.
      F(LP,NVFU)=0.
      F(LP,NVCO)=0.
      GO TO 216
  217 TEMP(I,J,K)=TIN(I)
      F(LP,NVFUOX)=FUOX(I)
      FEXIT=FUOX(I)-RATIO2*(1.-FUOX(I))/RATIO1
      F(LP,NVFU)=AMAX1(FEXIT,C.)
      F(LP,NVCO)=0.
  216 J=JWLO(I,4)
      LP=KM(K)+JM(J)+I
      TEMP(I,J,K)=TCYLW
      IF (J.EQ.MP1) GO TO 444
      TEMP(I,J,K)=TINLW
  444 F(LP,NVFU)=0.
      F(LP,NVCO)=0.
  206 F(LP,NVFUOX)=0.
      DO 210 J=1,MP1
      I=IWLI(J,4)-1
      LP=KM(K)+JM(J)+I
      IF (J.GE.JSW1.AND.J.LE.JSW2) GO TO 212
      TEMP(I,J,K)=TINLW
      F(LP,NVFUOX)=0.
```

```
      F(LP,NVFU)=0.
      F(LP,NVCO)=0.
      GO TO 213
  212 TEMP(I,J,K)=TSW
      F(LP,NVFUOX)=FUOXSW
      F(LP,NVFU)=FUMSW
      F(LP,NVCO)=0.
  213 I=IWLO(J,4)+I
      LP=KM(K)+JM(J)+I
      IF (J.GT.JWOI.AND.J.LT.JWOO) GO TO 214
      TEMP(I,J,K)=TINLW
      F(LP,NVFUOX)=0.
      F(LP,NVFU)=0.
      F(LP,NVCO)=0.
      GO TO 210
  214 F(LP,NVFUOX)=FUOX(LP1)
      FEXIT=FUOX(LP1)-RATIO2*(1.-FUOX(LP1))/RATIO1
      F(LP,NVFU)=AMAX1(FEXIT,0.)
      F(LP,NVTE)=TIN(I)
      F(LP,NVCO)=0.
  210 CONTINUE
C ----INJECTION POINTS
      IF (NUINJ.LE.0) GO TO 495
      DO 218 II=1,NUINJ
      I=IUINJ(II)-1
      J=JUINJ(II)
      LP=KM(K)+JM(J)+I
      F(LP,NVFUOX)=0.
      F(LP,NVFU)=0.
      F(LP,NVCO)=0.
  218 TEMP(I,J,K)=TUINJ(II)
  495 CONTINUE
      IF (NVINJ.LE.0) GO TO 220
      DO 222 II=1,NVINJ
      I=IVINJ(II)
      J=JVINJ(II)
      K=KVINJ(II)
      LP=KM(K)+JM(J)+I
      F(LP,NVFUOX)=0.
      F(LP,NVFU)=0.
      F(LP,NVCO)=0.
  222 TEMP(I,J,K)=TVINJ(II)
  220 CONTINUE
C --------- HERE PP IS PHI, P IS MFU AND DU IS MCO
      WRITE (NT*1) PP,P,DU
C +-+-+-+-+-+-+-+-+-+-+-+-+  ENTHALPY  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      DO 276 K=1,NPI
      DO 276 J=1,MPI
      IS=IWLI(J,5)
      IE=IWLO(J,5)
      KJM=KM(K)+JM(J)
      DO 276 I=IS,IE
      LP=KJM+I
      T=TEMP(I,J,K)
      FUB=F(LP,NVFUOX)-F(LP,NVFU)
      FLPOX=RATIO1*F(LP,NVFU)+RATIO3*F(LP,NVCO)+RATIO2-(RATIO1+RATIO2)*
     1F(LP,NVFUOX)
      FLPOX=AMAX1(FLPOX,0.)
      FLPH2O=4YY*WH2O*FUB/WFU/ .
      FLPCO2=WCO2*CXX*FUB/WFU-WCO2*F(LP,NVCO)/WCO
      FLPN2=1.-F(LP,NVFU)-FLPCO2-F(LP,NVCO)-FLPOX-FLPH2O
      HPI=F(LP,NVFU)*HDR(T,1)+FLPCO2*HDR(T,2)+F(LP,NVCO)*HDR(T,3)+
     1    FLPOX*HDR(T,4)+FLPH2O*HDR(T,5)+FLPN2*HDR(T,12)
      F(LP,NVH)=HPI
  276 CONTINUE
C +-+-+-+-+-+-+-+-+-+-+-+-  FX,FY,FZ AND FAV  -+-+-+-+-+-+-+-+-+-+-+-+-+
      DO 791 K=1,NPI
      DO 791 J=1,MPI
      KJM=KM(K)+JM(J)
      IS=IWLI(J,5)
      IE=IWLO(J,5)
      DO 791 I=IS,IE
      LP=KJM+I
      ST4=SIGMA*TEMP(I,J,K)**4
      F(LP,NVRX)=ST4
      F(LP,NVRY)=ST4
      F(LP,NVRZ)=ST4
```

```
540       701 FILP,HVFAV1=ST4                                    AL   501
      C ---------- HERE DY IS ENTHALPY, DW IS FAV                  AL   502
          WRITE (NTP1) DY,DW                                       AL   503
      C ---------- HERE U IS FX, V IS FY, W IS FZ                  AL   504
          WRITE (NTP1) U,V,W                                       AL   505
545       RETURN                                                   AL   506
          END                                                      AL   507
```

CARD NR.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
87	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
92	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
[illegible]	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
[illegible]	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
[illegible]	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
[illegible]	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
[illegible]	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
314	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
321	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
333	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
348	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
379	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
416	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
432	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
[illegible]	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
529	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.

```
      SUBROUTINE ALLMOD                                                  AL        509
      COMMON F(500,7),DU(10,10,5),DV(10,10,5),DW(10,10,5),               COMFA       2
     1  RHO(10,10,5),VISC(10,10,5),SU(10,10),SP(10,10),DRHODP(10,10,5),  COMFA       3
     1  AXP(10,10),AXM(10,10),AYP(10,10),AYM(10,10),AZP(10,10),          COMFA       4
     2  AZM(10,10),CZ(10,10),CY(10),CZU(10,10),CYU(10),                  COMFA       5
     3  CZP(10,10),CYP(10),DIVG(10,10),NTP1,NTP2                         COMFA       6
      DIMENSION U(10,10,5),V(10,10,5),W(10,10,5),PP(10,10,5)             COMFA       7
      DIMENSION P(10,10,5),TEMP(10,10,5),GAM(10,10,5)                    COMFA       8
      EQUIVALENCE (F(1,1),U(1,1,1)),(F(1,2),V(1,1,1)),(F(1,3),W(1,1,1))  COMFA       9
      EQUIVALENCE (F(1,4),PP(1,1,1)),(F(1,5),P(1,1,1))                   COMFA      10
      EQUIVALENCE (F(1,6),TEMP(1,1,1)),(F(1,7),GAM(1,1,1))               COMFA      11
      COMMON/CYL/R(30),RM(30),RMV(30),YSR(30),YSVR(30),IPLAX             COMMON      2
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),        COMMON      3
     1  YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),      COMMON      4
     2  FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME                          COMMON      5
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NI,NJ,NK,NIJ,NIJNK,NV,    COMMON      6
     1  NNV,NGOTO,K,ISTR,JSTR,KSTR,NVM(20),KM(30),JM(30),ISTEP,          COMMON      7
     2  ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISWP,JSWP,RELAX(16),NP,   COMMON      8
     3  NRHO,NGAM,IWLI(30,5),IWLO(30,5),JWLO(40,5),JWLI(40,5),IWEI,      COMMON      9
     4  IWEO,NNI,JWII,JWIO,JWOI,JWCO,IDW,JKIN(30,30),IKIN(40,30)         COMMON     10
      COMMON/INDEX/IPAR,LPREF,ISTUM,INCOMP,ITRAD,NVRX,NVRY,NVRZ,JPLANE   COMMON     11
     1  ,PLAXMI,LVK,LVD,LVFUOX,LVFU,LVCO,LVH,LVRX,LVRY,LVRZ,NVF(13),     COMMON     12
     2  IJUMP,IRES,TITLE2(20),IMAX,JMAX,KMAX,NVCO,FUMCO,NVH2O,NVCO2,     COMMON     13
     3  NVN2                                                             COMMON     14
      COMMON/THERM/NVH,NVFU,NVOX,NVFUOX,NVTE,MODEN,IDK,FSTOIC,MFU,CP,    COMMON     15
     1  GASCON,RMOCON,UNICON,PRESS,NVFAV,TCYLW,TINLW,TLIP,ACOEF(4),      COMMON     16
     2  T4,QFAC,WFU,WCO2,WCO,WOX,WH2O,WN2,HYY,CXX,RATIO1,RATIO2,         COMMON     17
     3  RATIO3,RATIO4,HCO,TAN,ITWALL                                     COMMON     18
      COMMON/CTDMA/KEND,ICTDMA(13)                                       COMMON     19
      COMMON/MIS/APU,DEN,SMAX,SSUM,LASTEP,HTCEXT,CFR,EMISW,EMISIN,       COMGEN      2
     1  EMISR,TOUT,RTCO,EM1,RADIN,RADSUR,FMA,FK,SOFK,                    COMGEN      3
     2  FKFU,FOFU,TFUEL,WFMZ,FLO(40),TEMIN(40),MI(40),FUEL(40),FUOX(40) ,COMGEN      4
     3  UIN(40),TIN(40),FUELS(40),SEXIT,IGAM1(10),IGAM2(10)              COMGEN      5
      COMMON/TURB/NVK,NVD,C1,C2,CD,AK,DUIDXJ(3,3),AKFAC,ALFAC,           COMGEN      6
     1  MODEL,PR(13),PREF(13),PJAY(13),E                                 COMGEN      7
      COMMON/RAD/NVE,SIGMA,ABSOR,SCATR                                   COMGEN      8
      COMMON/REACT/ARCON1,PREXP1,CR1,ARCON2,PREXP2,CR2,MODER             COMGEN      9
      COMMON/DROPL/EVAP(192),NTP4,NFMZ,XG(3),YD(3),ZD(3),ALFA(3),        COMGEN     10
     1  BETA(3),DELTA(3),THETA1(3),THETA2(3),NSL(3),WFF(3),SMD(3),       COMGEN     11
     2  VFUEL(3),RFUEL(3),EVSU(64),NEVAP                                 COMGEN     12
      COMMON/INJEC/FLOWIN,IUINJ(20),JUINJ(20),VINJ(20),HUINJ(20),        COMGEN     13
     1  AUINJ(20),TUINJ(20),IVINJ(20),JVINJ(20),KVINJ(20),WINJ(20),      COMGEN     14
     2  EVINJ(20),DVINJ(20),AVINJ(20),TVINJ(20),NUINJ,NVINJ,JSW1,JSW2,   COMGEN     15
     3  USW,VSW,AFSW,FSW,TSW,WSW,SWNO,RHOSW                              COMGEN     16
C  ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** *               AL        512
      ENTRY FMOD                                                         AL        513
      NVFF=NVF(NV)                                                       AL        514
C -------------- CYCLIC BOUNDARY CONDITIONS ----------------------        AL        515
 1044 DO 1002 J=1,MP1                                                    AL        516
      DO 1002 I=1,LP1                                                    AL        517
      LIJ=I+JM(J)                                                        AL        518
      LP2=I+JM(J)+KM(2)                                                  AL        519
      LPN=LIJ+KM(N)                                                      AL        520
      LPNP1=LIJ+KM(NP1)                                                  AL        521
      F(LIJ,NVFF)=F(LPN,NVFF)                                            AL        522
      F(LPNP1,NVFF)=F(LP2,NVFF)                                          AL        523
 1002 CONTINUE                                                           AL        524
 1001 CONTINUE                                                           AL        525
      IF (NV.NE.LVFU.AND.NV.NE.LVCO) GO TO 1010                          AL        526
      DO 1020 K=1,NP1                                                    AL        527
      DO 1020 J=1,MP1                                                    AL        528
      KJM=KM(K)+JM(J)                                                    AL        529
      DO 1020 I=1,LP1                                                    AL        530
      LP=KJM+I                                                           AL        531
      F(LP,NVFF)=AMAX1(F(LP,NVFF),0.)                                    AL        532
      IF (NV.EQ.LVCO) F(LP,NVFF)=AMIN1(F(LP,NVFF),.25)                   AL        533
 1020 CONTINUE                                                           AL        534
 1010 CONTINUE                                                           AL        535
      RETURN                                                             AL        536
C  ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** *               AL        537
      ENTRY VELMOD                                                       AL        538
      DO 1000 K=1,NP1                                                    AL        539
      DO 1000 J=JSW1,JSW2                                                AL        540
      WIN=WSW*R(J)/R(JSW2)                                               AL        541
      I=IWLI(J,4)-1                                                      AL        542
      W(I,J,K)=W(I,J,K)+.05*WIN                                          AL        543
      IF (ABS(W(I,J,K)).GT.ABS(WIN)) W(I,J,K)=WIN                        AL        544
```

```
 1003  CONTINUE                                                    AL  545
 1003  CONTINUE                                                    AL  546
       DO 2005 J=2,M                                               AL  547
       DO 2005 I=2,L                                               AL  548
       W(I,J,2)=W(I,J,MP1)                                         AL  549
 2007  DW(I,J,2)=DW(I,J,MP1)                                       AL  550
 2005  CONTINUE                                                    AL  551
C -------   SATISFY CONTINUITY AT EXIT PLANE                       AL  552
       RHOA=0.0                                                    AL  553
       FLOWOT=0.0                                                  AL  554
       INDX=0                                                      AL  555
       DO 755 K=2,M                                                AL  556
       JS=JWLI(LP1,4)+1                                            AL  557
       JE=JWLO(LP1,4)-1                                            AL  558
       DO 755 J=JS,JE                                              AL  559
       RHO(LP1,J,K)=RHO(L,J,K)                                     AL  560
       RDA=YSR(J)*ZS(K)*RHO(LP1,J,K)                               AL  561
       RHOA=RHOA+RDA                                               AL  562
       FLOWOT=FLOWOT+U(L,J,K)*RDA                                  AL  563
       IF (U(L,J,K).GE.0.0) GO TO 755                              AL  564
       INDX=1                                                      AL  565
  755  CONTINUE                                                    AL  566
       UADD=(FLOWIN-FLOWOT)/RHOA                                   AL  567
       SEXIT=1.-FLOWOT/FLOWIN                                      AL  568
       UMEAN=FLOWIN/RHOA                                           AL  569
       DO 756 K=2,M                                                AL  570
       JS=JWLI(LP1,4)+1                                            AL  571
       JE=JWLO(LP1,4)-1                                            AL  572
       DO 756 J=JS,JE                                              AL  573
       IF (INDX) 757,757,758                                       AL  574
  757  U(LP1,J,K)=U(L,J,K)+UADD                                    AL  575
       GO TO 756                                                   AL  576
  758  U(LP1,J,K)=UMEAN                                            AL  577
  756  CONTINUE                                                    AL  578
       RETURN                                                      AL  579
C  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  *  AL  580
       ENTRY DENMOD                                                AL  581
       IF (NVINJ.LE.0) GO TO 750                                   AL  582
       DO 749 II=1,NVINJ                                           AL  583
       I=IVINJ(II)                                                 AL  584
       K=KVINJ(II)                                                 AL  585
       J=JVINJ(II)                                                 AL  586
       M1=J                                                        AL  587
       IF (J.EQ.JWLI(I,4)) M1=J+1                                  AL  588
       AREA=XS(I)*RM(M1)*ZS(K)                                     AL  589
       RHOINJ=AVINJ(II)/ABS(VINJ(II))/AREA                         AL  590
  749  RHO(I,J,K)=RHOINJ                                           AL  591
  750  CONTINUE                                                    AL  592
       DO 2060 J=2,M                                               AL  593
       DO 2060 I=2,L                                               AL  594
       RHO(I,J,MP1)=.5*(RHO(I,J,2)+RHO(I,J,M))                     AL  595
       RHO(I,J,1)=RHO(I,J,MP1)                                     AL  596
 2060  CONTINUE                                                    AL  597
       DO 759 K=1,MP1                                              AL  598
       DO 2061 J=JSW1,JSW2                                         AL  599
       I=IWLI(J,4)-1                                               AL  600
 2061  RHO(I,J,K)=RHOSW                                            AL  601
 2099  CONTINUE                                                    AL  602
 2064  IF (NUINJ.LE.0) GO TO 760                                   AL  603
       DO 759 II=1,NUINJ                                           AL  604
       I=IUINJ(II)-1                                               AL  605
       J=JUINJ(II)                                                 AL  606
       AREA=YSR(J)*(Z(MP1)-Z(1))                                   AL  607
  759  RHO(I,J,K)=2.*AUINJ(II)/AREA/UINJ(II)-RHO(I+1,J,K)          AL  608
  760  CONTINUE                                                    AL  609
       RETURN                                                      AL  610
C  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  *  AL  611
       ENTRY GAMOD                                                 AL  612
       DO 3000 K=1,MP1                                             AL  613
       DO 3007 I=1,LP1                                             AL  614
       J=JWLO(I,4)                                                 AL  615
       IF (IKIN(I,K).EQ.2.OR.IKIN(I,K).EQ.3) GO TO 3003            AL  616
       IF (IGAM1(NW).EQ.0) GO TO 3003                              AL  617
       YPLUS=VISC(I,J,K)                                           AL  618
       IF (YPLUS.GT.11.5) GO TO 3001                               AL  619
       GAM(I,J,K)=AMU/PR(NW)                                       AL  620
       GO TO 3002                                                  AL  621
```

```
      3001 GAM(I,J,K)=AMU*YPLUS/PREF(NV)/(ALOG(E*YPLUS)/AK+PJAY(NV))         AL
           GO TO 3002                                                      AL
      3003 GAM(I,J,K)=0.                                                   AL
      3002 J=JWLI(I,4)                                                     AL
           IF ((NV.EQ.0.OR.(KIN(I,K).EQ.1.OR.KIN(I,K).EQ.3)) GO TO 3004   AL
           IF ((IGAM1(NV).EQ.0)) GO TO 3004                                AL
           YPLUS=VISC(I,J,K)                                               AL
           IF (YPLUS.GT.11.5) GO TO 3006                                   AL
           GAM(I,J,K)=AMU/PR(NV)                                           AL
           GO TO 3007                                                      AL
      3006 GAM(I,J,K)=AMU*YPLUS/PREF(NV)/(ALOG(E*YPLUS)/AK+PJAY(NV))         AL
           GO TO 3007                                                      AL
      3004 GAM(I,J,K)=0.                                                   AL
      3007 CONTINUE                                                        AL
           DO 3000 J=2,M                                                   AL
           I=IWLI(J,4)-1                                                   AL
           IF (JKIN(J,K).EQ.1) GO TO 3009                                  AL
           IF ((IGAM2(NV).EQ.0) GO TO 3009                                 AL
           YPLUS=VISC(I,J,K)                                               AL
           IF (YPLUS.GT.11.5) GO TO 3019                                   AL
           GAM(I,J,K)=AMU/PR(NV)                                           AL
           GO TO 3011                                                      AL
      3019 GAM(I,J,K)=AMU*YPLUS/PREF(NV)/(ALOG(E*YPLUS)/AK+PJAY(NV))         AL
           GO TO 3011                                                      AL
      3009 GAM(I,J,K)=0.                                                   AL
      3011 I=IWLO(J,4)+1                                                   AL
           IF ((J.GT.JWOI.AND.J.LT.JWOO)) GO TO 3012                       AL
           IF ((IGAM2(NV).EQ.0)) GO TO 3012                                AL
           YPLUS=VISC(I,J,K)                                               AL
           IF (YPLUS.GT.11.5) GO TO 3013                                   AL
           GAM(I,J,K)=AMU/PR(NV)                                           AL
           GO TO 3000                                                      AL
      3013 GAM(I,J,K)=AMU*YPLUS/PREF(NV)/(ALOG(E*YPLUS)/AK+PJAY(NV))         AL
           GO TO 3000                                                      AL
      3012 GAM(I,J,K)=0.                                                   AL
      3000 CONTINUE                                                        AL
           DO 3014 I=2,L                                                   AL
           DO 3014 J=2,M                                                   AL
           GAM(I,J,1)=.5*(GAM(I,J,2)+GAM(I,J,N))                           AL
           GAM(I,J,NP1)=GAM(I,J,1)                                         AL
           IF (NV.EQ.3) GAM(I,J,NP1)=GAM(I,J,2)                            AL
      3014 CONTINUE                                                        AL
           RETURN                                                          AL
C **     **   **   **   **   **   **   **   **   **   **   **   **   **   **   **   **   AL
           ENTRY SOMAS                                                     AL
           DO 124 I=1,LP1                                                  AL
           DO 124 J=1,MP1                                                  AL
       124 DIVG(I,J)=0.                                                    AL
           GO TO (266,267,268,269), NGOTO                                  AL
C -----------    U-VELOCITY                                                AL
       266 CONTINUE                                                        AL
       270 IF (NFMZ.LE.0) GO TO 271                                        AL
           DO 273 J=2,M                                                    AL
           KJK=(K-2)*(NI-2)*(NJ-2)+(J-2)*(NI-2)                            AL
           IS=IWLI(J,NGOTO)                                                AL
           IE=IWLO(J,NGOTO)                                                AL
           DO 273 I=IS,IE                                                  AL
           LPC=KJK+(I-1)                                                   AL
           LIMC=LPC-1                                                      AL
           DIVG(I,J)=DIVG(I,J)-FXM(I-1)*EVAP(LIMC)-FXP(I)*EVAP(LPC)        AL
           IF (I.EQ.3) DIVG(I,J)=DIVG(I,J)-FXP(2)*EVAP(LIMC)               AL
           IF (I.EQ.L) DIVG(I,J)=DIVG(I,J)-FXM(L)*EVAP(LPC)                AL
       273 CONTINUE                                                        AL
       271 CONTINUE                                                        AL
           RETURN                                                          AL
C -----------    V-VELOCITY                                                AL
       267 CONTINUE                                                        AL
       276 IF (NFMZ.LE.0) GO TO 274                                        AL
           DO 277 J=3,M                                                    AL
           KJK=(K-2)*(NI-2)*(NJ-2)+(J-2)*(NI-2)                            AL
           IS=IWLI(J,NGOTO)                                                AL
           IE=IWLO(J,NGOTO)                                                AL
           DO 277 I=IS,IE                                                  AL
           LPC=KJK+(I-1)                                                   AL
           LYMC=LPC-(NI-2)                                                 AL
           DIVG(I,J)=DIVG(I,J)-FYM(J-1)*EVAP(LYMC)-FYP(J)*EVAP(LPC)        AL
           IF (J.EQ.3) DIVG(I,J)=DIVG(I,J)-FYP(2)*EVAP(LYMC)               AL
```

```
      IF (J.EQ.M) DIVG(I,J)=DIVG(I,J)-FYM(M)*EVAP(LPC)
  277 CONTINUE
  276 CONTINUE
      RETURN
C ---------- V-VELOCITY
  269 CONTINUE
  279 IF (NFNZ.LE.0) GO TO 281
      DO 282 J=2,M
      KJK=(K-2)*(NI-2)*(NJ-2)+(J-2)*(NI-2)
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      DO 282 I=IS,IE
      LPC=KJK+(I-1)
      LZNC=LPC-(NI-2)*(NJ-2)
      LIJ=(J-2)*(NI-2)+(I-1)
      DIVG(I,J)=DIVG(I,J)-FZM(K-1)*EVAP(LZNC)
      IF (K.LT.NP1) DIVG(I,J)=DIVG(I,J)-FZP(K)*EVAP(LPC)
      IF (K.EQ.NP1) DIVG(I,J)=DIVG(I,J)-FZP(2)*EVAP(LIJ)
  282 CONTINUE
  281 CONTINUE
      RETURN
C ---------- OTHER VARIABLES
  263 CONTINUE
  283 IF (NFNZ.LE.0) GO TO 285
      DO 286 J=2,M
      KJK=(K-2)*(NI-2)*(NJ-2)+(J-2)*(NI-2)
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      DO 286 I=IS,IE
      LPC=KJK+(I-1)
      DIVG(I,J)=DIVG(I,J)-EVAP(LPC)
  286 CONTINUE
  285 CONTINUE
      RETURN
C  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  *
      ENTRY SOMOD
COME HERE FOR SLOT COEFFICIENT MODS.
   54 IF (NUINJ.LE.0) GO TO 52
      DO 49 II=1,NUINJ
      I=IUINJ(II)
      J=JUINJ(II)
      IF (J.EQ.JWLI(I,4)+1) GO TO 149
      M1=J-1
      IF (NV.EQ.1) AVP(I,M1)=.5*AVP(I,M1)
      IF (NV.EQ.1) AVP(I-1,M1)=.5*AVP(I-1,M1)
      IF (NV.GT.2) AVP(I-1,M1)=0.
      IF (NV.NE.1) AIP(I-2,J)=0.
      IF (NV.EQ.LVPX) AXM(I,J)=0.
      GO TO 49
  149 M1=J+1
      IF (NV.EQ.1) AVM(I,M1)=.5*AVM(I,M1)
      IF (NV.EQ.1) AVM(I-1,M1)=.5*AVM(I-1,M1)
      IF (NV.GT.2) AVM(I-1,M1)=0.
      IF (NV.NE.1) AIP(I-2,J)=0.
      IF (NV.EQ.LVPX) AXM(I,J)=0.
   49 CONTINUE
   52 CONTINUE
C *-*-*-*-*-*-*-*-*-*-*-  PRESSURE PERTABATION  *-*-*-*-*-*-*-*-*-*-*-*-*-
      IF(NV.NE.4) GO TO 290
      IF (NUINJ.LE.0) GO TO 99
      DO 99 II=1,NUINJ
      I=IUINJ(II)-1
      J=JUINJ(II)
      SU(I,J)=0.
   98 SP(I,J)=-1.E30
   99 CONTINUE
COME HERE FOR DROPLET EVAPORATION TERMS
      IF (NFNZ.LE.0) GO TO 344
      DO 346 J=2,M
      KJK=(K-2)*(NI-2)*(NJ-2)+(J-2)*(NI-2)
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      DO 346 I=IS,IE
      LPC=KJK+(I-1)
  346 SU(I,J)=SU(I,J)+EVAP(LPC)
  344 CONTINUE
      IF(K.NE.2) GO TO 101
```

```
      SMAX=0.
      SSUM=0.
  101 CONTINUE
      DO 100 J=2,M
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      DO 100 I=IS,IE
      ASU=ABS(SU(I,J))
      SSUM=SSUM+ASU
      IF (ASU.LT.SMAX) GO TO 100
      IMAX=I
      JMAX=J
      KMAX=K
      SMAX=ASU
  100 CONTINUE
      IF(K.NE.M) GO TO 102
      SMAX=SMAX/FLOWIN
      SSUM=SSUM/FLOWIN
  102 CONTINUE
  200 CONTINUE
C -------------------   TURBULENCE DISSIPATION   ---------------------
      IF (NV.NE.LVD) GO TO 300
C  COME HERE FOR CYLINDRICAL WALL SOURCE TERMS
      DO 201 I=2,L
      J=JWLO(I,NGOTO)-1
      IF (IKIN(I,K).EQ.2.OR.IKIN(I,K).EQ.3) GO TO 1201
      DIST=.5*YDIF(J+1)
      IF (J.EQ.M) DIST=YDIF(MP1)
      LP=KM(K)+JM(J)+I
      RTCDK=RTCDF(LP,NVK)
      SU(I,J)=1.E30*RTCDK*SQRT(RTCDK)/(AK*DIST)
      SP(I,J)=-1.E30
 1201 IF (ID+1) 221,201,1298
 1298 J=JWLI(I,NGOTO)+1
      IF (IKIN(I,K).EQ.1.OR.IKIN(I,K).EQ.3) GO TO 201
      DIST=.5*YDIF(J)
      IF (J.EQ.2) DIST=YDIF(2)
      LP=KM(K)+JM(J)+I
      RTCDK=RTCDF(LP,NVK)
      SU(I,J)=1.E30*RTCDK*SQRT(RTCDK)/(AK*DIST)
      SP(I,J)=-1.E30
  201 CONTINUE
C  COME HERE FOR SLOT MODIFICATIONS
      IF (NUINJ.LE.0) GO TO 710
      DO 709 II=1,NUINJ
      I=IUINJ(II)-1
      J=JUINJ(II)
      M1=J-1
      IF (J.EQ.JWLI(I,NGOTO)+1) M1=J+1
      M2=AMAX0(M1,J)
      LP=KM(K)+JM(M1)+I
      RTCDK=RTCDF(LP,NVK)
      SKE=AKFAC*(UINJ(II)**2+WUINJ(II)**2)
      SLM=ALFAC*YS(J)
      SU(I,J)=1.E30*CD*SKE**1.5/(SLM+1.E-30)
      SP(I,J)=-1.E30
      SU(I,M1)=1.E30*RTCDK*SQRT(RTCDK)/(AK*.5*YDIF(M2))
      SP(I,M1)=-1.E30
  709 CONTINUE
  710 CONTINUE
C  COME HERE FOR INLET WALL SOURCE TERMS
      DO 202 J=2,MM1
      I=IWLI(J,NGOTO)
      IF (JKIN(J,K).EQ.1) GO TO 1202
      LP=I+JM(J)+KM(K)
      RTCDK=RTCDF(LP,NVK)
      DIST=.5*XDIF(I)
      IF (I.EQ.2) DIST=XDIF(2)
      SU(I,J)=1.E30*RTCDK*SQRT(RTCDK)/(AK*DIST)
      SP(I,J)=-1.E30
 1202 I=IWLO(J,NGOTO)
      IF (J.GT.JOI.AND.J.LT.JOO) GO TO 202
      LP=I+JM(J)+KM(K)
      RTCDK=RTCDF(LP,NVK)
      DIST=.5*XDIF(I+1)
      IF (I.EQ.L) DIST=XDIF(LPI)
      SU(I,J)=1.E30*RTCDK*SQRT(RTCDK)/(AK*DIST)
```

```
      SP(I,J)=-1.E30                                              AL     853
  202 CONTINUE                                                     AL     854
C -------------------------------- VELOCITY ------------------------ AL     855
  300 IF (NU.NE.1) GO TO [illegible]                               AL     856
C ---- FOR SLOT ORIFICATIONS                                        AL     857
      IF ([illegible]) GO TO 720                                   AL     858
      DO 710 [illegible]                                           AL     859
      I=IJ(N,1)                                                    AL     860
      J=IJ(N,2)                                                    AL     861
      SU(I,J)=1.E30*[illegible]                                    AL     862
      SP(I,J)=-1.E30                                               AL     863
  710 SP(I,J)=-1.E30                                               AL     864
  720 CONTINUE                                                     AL     865
C ---- FOR DROPLET EVAPORATION TERMS                                AL     866
      IF (NFN2.[illegible]) GO TO 321                              AL     867
      IF ([illegible]) REWIND NTP4                                 AL     868
      READ (NTP4) [illegible]                                      AL     869
      DO 322 [illegible]                                           AL     870
      [illegible](J-2)*(NI-2)                                      AL     871
      [illegible]                                                  AL     872
      [illegible]                                                  AL     873
      DO 322 [illegible]                                           AL     874
      [illegible]                                                  AL     875
      [illegible]                                                  AL     876
      LI=(J-2)*(NI-2)+(I-1)                                        AL     877
      SU(I,J)=SU(I,J)+[illegible](LI)                              AL     878
      SP(I,J)=SP(I,J)-[illegible]*EVAP(LPC)-[illegible]*EVAP(LPC)  AL     879
      IF ([illegible]) SP(I,J)=SP(I,J)-FP(2)*EVAP(LPC)             AL     880
      IF ([illegible]) SP(I,J)=SP(I,J)-FP(1)*EVAP(LPC)             AL     881
  322 CONTINUE                                                     AL     882
  321 CONTINUE                                                     AL     883
C -------------------------------- W-VELOCITY ---------------------- AL     884
  400 IF(NW.NE.1) GO TO 500                                        AL     885
C ---- FOR SLOT ORIFICATIONS                                        AL     886
      IF ([illegible]) GO TO 362                                   AL     887
      DO 710 [illegible]                                           AL     888
      [illegible]                                                  AL     889
      [illegible]                                                  AL     890
      [illegible]                                                  AL     891
      IF ([illegible]) [illegible]                                 AL     892
      [illegible]                                                  AL     893
      [illegible]                                                  AL     894
      [illegible]                                                  AL     895
      [illegible]                                                  AL     896
      [illegible]                                                  AL     897
      [illegible]                                                  AL     898
      [illegible]                                                  AL     899
      [illegible]                                                  AL     900
  714 SP(I,J)=-1.E30                                               AL     901
  362 CONTINUE                                                     AL     902
C ---- FOR DROPLET EVAPORATION TERMS                                AL     903
      IF ([illegible]) GO TO 325                                   AL     904
      READ (NTP4) [illegible]                                      AL     905
      DO 326 J=2,M                                                 AL     906
      [illegible](J-2)*(NI-2)                                      AL     907
      [illegible]                                                  AL     908
      [illegible]                                                  AL     909
      DO 326 [illegible]                                           AL     910
      [illegible]                                                  AL     911
      [illegible]                                                  AL     912
      [illegible]                                                  AL     913
      [illegible](LI)                                              AL     914
      SP(I,J)=SP(I,J)-[illegible]*EVAP(LZPC)                       AL     915
      IF ([illegible]) GO TO 347                                   AL     916
      SP(I,J)=SP(I,J)-FZP(1)*EVAP(LPC)                             AL     917
      GO TO 326                                                    AL     918
  347 SP(I,J)=SP(I,J)-FZP(2)*EVAP(LIA)                             AL     919
  326 CONTINUE                                                     AL     920
  325 CONTINUE                                                     AL     921
C ------------------ TURBULENT KINETIC ENERGY ----------------------- AL     922
  500 IF ([illegible]) GO TO [illegible]                           AL     923
C ---- FOR SLOT ORIFICATIONS                                        AL     924
      IF ([illegible]) GO TO 652                                   AL     925
      DO 751 [illegible]                                           AL     926
      [illegible]                                                  AL     927
      [illegible]                                                  AL     928
      [illegible]                                                  AL     929
```

```
      IF (J.EQ.JWLI(I,NGOTO)+1) M1=J+1                                   AL   930
      WALKE=CFPO.25*((U(I,M1,K)+U(I+1,M1,K))**2+(W(I,M1,K)+W(I,M1,K+1))  AL   931
     1 **2)/RTCD                                                         AL   932
      WALKE=AMAX1(WALKE,1.)                                              AL   933
      SKE=AKFAC*(UINJ(II)**2+WINJ(II)**2)                                AL   934
      SU(I,J)=1.E30*SKE                                                  AL   935
      SP(I,J)=-1.E30                                                     AL   936
      SU(I,M1)=1.E30*WALKE                                               AL   937
  731 SP(I,M1)=-1.E30                                                    AL   938
  682 CONTINUE                                                           AL   939
C ------------------  U-VELOCITY  ---------------------------            AL   940
  600 IF(NV.NE.2) GO TO 700                                              AL   941
COME HERE FOR SLOT MODIFICATIONS                                         AL   942
      IF (NUINJ.LE.0) GO TO 733                                          AL   943
      DO 730 II=1,NUINJ                                                  AL   944
      I=IUINJ(II)-1                                                      AL   945
      J=JUINJ(II)                                                        AL   946
      SP(I,J+1)=-1.E30                                                   AL   947
  730 SP(I,J)=-1.E30                                                     AL   948
  733 CONTINUE                                                           AL   949
COME HERE FOR DROPLET EVAPORATION TERMS                                  AL   950
      IF (NFMAX.LE.2) GO TO 323                                          AL   951
      READ (NTP4) EVSU                                                   AL   952
      DO 324 J=3,M                                                       AL   953
      CJK=(K-2)*(NI-2)*(NJ-2)+(J-2)*(NI-2)                               AL   954
      IS=IWLI(J,NGOTO)                                                   AL   955
      IE=IWLO(J,NGOTO)                                                   AL   956
      DO 324 I=IS,IE                                                     AL   957
      LPC=CJK+(I-1)                                                      AL   958
      LYMC=LPC-(NI-2)                                                    AL   959
      LIJ=(J-2)*(NI-2)+(I-1)                                             AL   960
      SU(I,J)=SU(I,J)+EVSU(LIJ)                                          AL   961
      SP(I,J)=SP(I,J)-FYM(J-1)*EVAP(LYMC)-FYP(J)*EVAP(LPC)               AL   962
      IF (J.EQ.3) SP(I,J)=SP(I,J)-FYP(2)*EVAP(LYMC)                      AL   963
      IF (J.EQ.M) SP(I,J)=SP(I,J)-FYM(M)*EVAP(LPC)                       AL   964
  324 CONTINUE                                                           AL   965
  323 CONTINUE                                                           AL   966
C ---------------------  ENTHALPY  ---------------------------           AL   967
  700 IF (NV.NE.LVH) GO TO 800                                           AL   968
COME HERE FOR CYLINDRICAL WALL SOURCE TERMS                              AL   969
      DO 891 I=2,L                                                       AL   970
      J=JWLO(I,NGOTO)-1                                                  AL   971
      IF (IWIN(I,K).EQ.2.OR.IWIN(I,K).EQ.3) GO TO 1001                   AL   972
      WTC=.5*SQRT((U(I,J,K)+U(I+1,J,K))**2+(W(I,J,K)+W(I,J,K+1))**2)    AL   973
     1 *RHO(I,J,K)*CFD                                                   AL   974
      SU(I,J)=SU(I,J)+TCONM(J+1)*ZS(K)*RS(I)*CP*(TCYL-TEMP(I,J,K))       AL   975
      IF (IDW) 891,891,1001                                              AL   976
 1001 J=JWLI(I,NGOTO)+1                                                  AL   977
      IF (IWIN(I,K).EQ.1.OR.IWIN(I,K).EQ.3) GO TO 891                    AL   978
      WTC=.5*SQRT((U(I,J,K)+U(I+1,J,K))**2+(W(I,J,K)+W(I,J,K+1))**2)    AL   979
     1 *RHO(I,J,K)*CFD                                                   AL   980
      SU(I,J)=SU(I,J)+TCONM(J)*ZS(K)*RS(I)*CP*(TCYL-TEMP(I,J,K))         AL   981
  891 CONTINUE                                                           AL   982
COME HERE FOR SLOT MODIFICATIONS                                         AL   983
      IF (NJINJ.LE.0) GO TO 862                                          AL   984
      DO 736 II=1,NUINJ                                                  AL   985
      I=IUINJ(II)-1                                                      AL   986
      J=JUINJ(II)                                                        AL   987
      M1=J-1                                                             AL   988
      IF (J.EQ.JWLI(I,NGOTO)+1) M1=J+1                                   AL   989
      M2=AMAX0(J,M1)                                                     AL   990
      WTC=.5*(U(I-1,J,K)+U(I-1,J,K+1))*RHO(I-1,J,K)*CFD                  AL   991
      WTC=AMAX1(ABS(WTC),1.E-20)                                         AL   992
      SU(I-1,J)=SU(I-1,J)+WTC*CP*ZS(K)*RS(I)*CP*(TLIP-TEMP(I-1,J,K))     AL   993
      WTC=.5*SQRT((U(I,M1,K)+U(I+1,M1,K))**2+(W(I,M1,K)+W(I,M1,K+1))     AL   994
     1 **2)*RHO(I,M1,K)*CFD                                              AL   995
      SU(I,M1)=SU(I,M1)+WTC*TCONM(M2)*ZS(K)*RS(I)*CP*(TLIP-TEMP(I,M1,K)) AL   996
      WTI=RAT(2)*SH*(UINJ(II),K)*(1.-RAT(2))*SH*(UINJ(II)+12)            AL   997
      SU(I,J)=1.E30*WTI                                                  AL   998
  736 SP(I,J)=-1.E30                                                     AL   999
  862 CONTINUE                                                           AL  1000
COME HERE FOR INLET WALL SOURCE TERMS                                    AL  1001
      DO 803 J=2,M                                                       AL  1002
      I=IWLI(J,NGOTO)                                                    AL  1003
      IF (JWIN(J,K).EQ.1) GO TO 1003                                     AL  1004
      WTC=.5*(W(I,J,K)+W(I,J,K+1))*RHO(I,J,K)*CFD                        AL  1005
      WTC=ABS(WTC)                                                       AL  1006
```

```
      AREA=YSR(J)*ZS(K)
      SU(I,J)=SU(I,J)+HTC*AREA*CP*(TINLW-TEMP(I,J,K))
 1003 I=IWLO(J,MGOTO)
      IF (J.GT.JWOI.AND.J.LT.JWOO) GO TO 903
      LP=I+JM(J)+KM(K)
      HTC=.5*(W(I,J,K)+W(I,J,K+1))*RHO(I,J,K)*CFP
      HTC=ABS(HTC)
      AREA=YSR(J)*ZS(K)
      SU(I,J)=SU(I,J)+HTC*AREA*CP*(TINLW-TEMP(I,J,K))
  903 CONTINUE
COME HERE FOR DROPLET EVAPORATION TERMS
      IF (NFMZ.LE.0) GO TO 315
      DO 316 J=2,M
      KJK=(K-2)*(MI-2)*(MJ-2)+(J-2)*(MI-2)
      IS=IWLI(J,MGOTO)
      IE=IWLO(J,MGOTO)
      DO 316 I=IS,IE
      LPC=KJK+(I-1)
      SU(I,J)=SU(I,J)+EVAP(LPC)*HDR(TFUEL,I)
  316 SP(I,J)=SP(I,J)-EVAP(LPC)
  315 CONTINUE
C     +-+-+-+-+-+-+-+-+-+    PHI (TOTAL FUEL)   +-+-+-+-+-+-+-+-+-+-+-+-+-+-
  800 IF (NV.NE.LVFUDX) GO TO 850
COME HERE FOR SLOT MODIFICATIONS
      IF (NUINJ.LE.0) GO TO 851
      DO 737 II=1,NUINJ
      I=IUINJ(II)-1
      J=JUINJ(II)
      SU(I,J)=0.
  737 SP(I,J)=-1.E30
  851 CONTINUE
COME HERE FOR DROPLET EVAPORATION TERMS
      IF (NFMZ.LE.0) GO TO 317
      DO 318 J=2,M
      KJK=(K-2)*(MI-2)*(MJ-2)+(J-2)*(MI-2)
      IS=IWLI(J,MGOTO)
      IE=IWLO(J,MGOTO)
      DO 318 I=IS,IE
      LPC=KJK+(I-1)
      SU(I,J)=SU(I,J)+EVAP(LPC)
  318 SP(I,J)=SP(I,J)-EVAP(LPC)
  317 CONTINUE
C     +-+-+-+-+-+-+-+-+-+-+-+-+-+    FUEL    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
  850 IF (NV.NE.LVFU) GO TO 961
COME HERE FOR SLOT MODIFICATIONS
      IF (NUINJ.LE.0) GO TO 899
      DO 742 II=1,NUINJ
      I=IUINJ(II)-1
      J=JUINJ(II)
  742 SP(I,J)=-1.E30
  899 CONTINUE
COME HERE FOR DROPLET EVAPORATION TERMS
      IF (NFMZ.LE.0) GO TO 319
      DO 320 J=2,M
      KJK=(K-2)*(MI-2)*(MJ-2)+(J-2)*(MI-2)
      IS=IWLI(J,MGOTO)
      IE=IWLO(J,MGOTO)
      DO 320 I=IS,IE
      LPC=KJK+(I-1)
      SU(I,J)=SU(I,J)+EVAP(LPC)
  320 SP(I,J)=SP(I,J)-EVAP(LPC)
  319 CONTINUE
C     +-+-+-+-+-+-+-+-+-+-+-+-+-+      CG       +-+-+-+-+-+-+-+-+-+-+-+-+-+-
  961 IF(NV.NE.LVCO) GO TO 950
COME HERE FOR SLOT MODIFICATION
      IF(NUINJ.LE.0) GO TO 950
      DO 952 II=1,NUINJ
      I=IUINJ(II)-1
      J=JUINJ(II)
      SU(I,J)=0.
  952 SP(I,J)=-1.E30
  959 CONTINUE
COME HERE FOR DROPLET EVAPORATION TERMS
  951 IF (NFMZ.LE.0) GO TO 950
      DO 957 J=2,M
      KJK=(K-2)*(MI-2)*(MJ-2)+(J-2)*(MI-2)
      IS=IWLI(J,MGOTO)
```

```
      IE=IWLO(J,NGOTO)
      DO 957 I=IS,IE
      LPC=KJK+(I-1)
  957 SP(I,J)=SP(I,J)-EVAP(LPC)
  956 CONTINUE
C +-+-+-+-+-+-+-+-+-+  X-DIRECTION RADIATION  +-+-+-+-+-+-+-+-+-+-+-+-
  900 IF (NV.NE.LVRX) GO TO 910
      DO 901 J=2,M
      I=IWLI(J,NGOTO)
      IF (IKIN(J,K).EQ.1) GO TO 902
      TEMPW=TEMP(I-1,J,K)
      SU(I,J)=SU(I,J)+EMI*SIGMA*TEMPW**4
      SP(I,J)=SP(I,J)-EMI
      GO TO 1901
902   CONTINUE
      SU(I,J)=SU(I,J)+RADIN
      SP(I,J)=SP(I,J)-1.
 1901 I=IWLO(J,NGOTO)
      IF (J.GT.JMOI.AND.J.LT.JMOO) GO TO 1902
      TEMPW=TEMP(I+1,J,K)
      SU(I,J)=SU(I,J)+EMI*SIGMA*TEMPW**4
      SP(I,J)=SP(I,J)-EMI
      GO TO 901
 1902 CONTINUE
      SU(L,J)=SU(L,J)+RADSUR
      SP(L,J)=SP(L,J)-1.
901   CONTINUE
COME HERE FOR SLOT MODIFICATIONS
      IF (NUINJ.LE.0) GO TO 903
      DO 743 II=1,NUINJ
      I=IUINJ(II)-1
      J=JUINJ(II)
      SU(I+1,J)=SU(I+1,J)+EMISR*SIGMA*TEMP(I,J,K)**4
      SP(I+1,J)=SP(I+1,J)-1
      TEMPW=TLIP
      SU(I-1,J)=SU(I-1,J)+EMI*SIGMA*TEMPW**4
  743 SP(I-1,J)=SP(I-1,J)-EMI
903   CONTINUE
C +-+-+-+-+-+-+-+-+-+  Y-DIRECTION RADIATION  +-+-+-+-+-+-+-+-+-+-+-+-
  910 IF (NV.NE.LVRY) GO TO 920
      DO 911 I=2,L
      J=JWLO(I,NGOTO)-1
      IF (IKIN(I,K).EQ.2.OR.IKIN(I,K).EQ.3) GO TO 904
      TEMPW=TEMP(I,J+1,K)
      SU(I,J)=SU(I,J)+EMI*SIGMA*TEMPW**4*RM(J+1)
      SP(I,J)=SP(I,J)-EMI*RM(J+1)
      GO TO 905
  904 SU(I,J)=SU(I,J)+RADIN
      SP(I,J)=SP(I,J)-1.
  905 IF (IDW) 911,911,1911
 1911 J=JWLI(I,NGOTO)+1
      IF (IKIN(I,K).EQ.1.OR.IKIN(I,K).EQ.3) GO TO 906
      TEMPW=TEMP(I,J-1,K)
      SU(I,J)=SU(I,J)+EMI*SIGMA*TEMPW**4*RM(J)
      SP(I,J)=SP(I,J)-EMI*RM(J)
      GO TO 911
  906 SU(I,J)=SU(I,J)+RADIN
      SP(I,J)=SP(I,J)-1.
911   CONTINUE
      IF (NUINJ.LE.0) GO TO 912
      DO 744 II=1,NUINJ
      I=IUINJ(II)-1
      J=JUINJ(II)
      M1=J-1
      IF (J.EQ.JWLI(I,NGOTO)+1) M1=J+1
      M2=MAX0(J,M1)
      TEMPW=TLIP
      SU(I,M1)=SU(I,M1)+EMI*SIGMA*TEMPW**4*RM(M2)
  744 SP(I,M1)=SP(I,M1)-EMI*RM(M2)
912   CONTINUE
  920 CONTINUE
      RETURN
C **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **
C -+-+-+-+-+-+-+-+-+-+-+-+  Z-DIRECTION RADIATION  -+-+-+-+-+-+-+-+-+-+-+
      ENTRY SORDOZ
      IF (NUINJ.LE.0) GO TO 1106
      DO 1102 II=1,NUINJ
```

```
SUBROUTINE ALLMOD      73/74    OPT=0 TRACE                    FTN 4.6+439        08/24/78  14.08.46        PAGE   18

              IF (JUIMJ(II).NE.JPLANE) GO TO 1102                                       AL     1161
              I=IUINJ(II)-1                                                              AL     1162
              DO 1104 K=2,N                                                              AL     1163
              SU(I,K)=0.                                                                 AL     1164
         1104 SP(I,K)=-1.E30                                                             AL     1165
         1102 CONTINUE                                                                   AL     1166
         1100 CONTINUE                                                                   AL     1167
              IS=IWLI(JPLANE,4)                                                          MM        1
              IE=IWLO(JPLANE,4)                                                          MM        2
              DO 921 I=IS,IE                                                             MM        3
              LPZ=I+J9(JPLANE)+KM(2)                                                     AL     1169
              LPN=I+J9(JPLANE)+KM(N)                                                     AL     1170
              GAMODL=.5*(GAM(I,JPLANE,2)+GAM(I,JPLANE,N))/R(JPLANE)/(ZDIF(NPl)+         AL     1171
             1 ZDIF(2))                                                                  AL     1172
              SU(I,2)=SU(I,2)+GAMODL*F(LPN,NVRZ)                                         AL     1173
              SP(I,2)=SP(I,2)-GAMODL                                                     AL     1174
              SU(I,N)=SU(I,N)+GAMODL*F(LPZ,NVRZ)                                         AL     1175
              SP(I,N)=SP(I,N)-GAMODL                                                     AL     1176
          921 CONTINUE                                                                   AL     1177
              RETURN                                                                     AL     1178
              END                                                                        AL     1179
```

CARD NR.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
59	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
72	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
89	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
103	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
131	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
140	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
696	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.

SUBROUTINE OUTPUT 73/74 OPT=0 TRACE FTN 4.6+439 09/24/79 14.09.46 PAGE 1

```
      SUBROUTINE OUTPUT(NTP)
      COMMON F(500,7),DU(10,10,5),DV(10,10,5),DW(10,10,5),
     1 RHO(10,10,5),VISC(10,10,5),SU(10,10),SP(10,10),DRHODP(10,10,5),
     1 AXP(10,10),AXM(10,10),AYP(10,10),AYM(10,10),AZP(10,10),
     2 AZM(10,10),CZ(10,10),CY(10),CZU(10,10),CYU(10),
     3 CZP(10,10),CYP(10),DIVG(10,10),NTP1,NTP2
      DIMENSION U(10,10,5),V(10,10,5),W(10,10,5),PP(10,10,5)
      DIMENSION P(10,10,5),TEMP(10,10,5),GAM(10,10,5)
      EQUIVALENCE (F(1,1),U(1,1,1)),(F(1,2),V(1,1,1)),(F(1,3),W(1,1,1))
      EQUIVALENCE (F(1,4),PP(1,1,1)),(F(1,5),P(1,1,1))
      EQUIVALENCE (F(1,6),TEMP(1,1,1)),(F(1,7),GAM(1,1,1))
      COMMON/CYL/R(30),RM(30),RMV(30),YSP(30),YSVP(30),IPLAX
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),
     1 YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),
     2 FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NI,NJ,NK,NIN,NINJNK,NV,
     1 NNV,NGOTO,K,ISTP,JSTP,KSTP,NVP(20),KM(30),JM(30),ISTEP,
     2 ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISWP,JSWP,RELAX(16),NP,
     3 NRHO,NGAM,IWLI(30,5),IWLO(30,5),JWLO(40,5),JWLI(40,5),IWFI,
     4 IWEO,NMI,JWII,JWIO,JWOI,JWOO,IOW,JWIN(30,30),IWIN(40,30)
      COMMON/INDEX/IPAR,LPREF,ISTUM,INCOMP,ITRAD,NVRX,NVRY,NVRZ,JPLANE
     1 ,PLAXM1,LVK,LVD,LVFUOX,LVFU,LVCO,LVM,LVRX,LVRY,LVRZ,NVF(13),
     2 IJUMP,IRES,TITLE2(20),IMAX,JMAX,KMAX,NVCO,FUNCC,NVH2O,NVCO2,
     3 NVN2
      COMMON/THERM/NVH,NVFU,NVOX,NVFUOX,NVTE,MODEN,IDF,FSTOIC,HFU,CP,
     1 GASCON,RHOCON,UNICON,PRESS,NVFAV,TCYLW,TINLW,TLIP,ACOEF(4),
     2 T4,DFAC,WFU,WCO2,WCO,WOX,WH2O,WN2,HYY,CXX,RATIO1,RATIO2,
     3 RATIO3,RATIO4,HCO,TAN,ITWALL
      COMMON/CTDMA/KEND,ICTDMA(13)
      COMMON/MIS/ARU,DEM,SMAX,SSUM,LASTEP,HTCEXT,CFR,EMISW,EMISIN,
     1 EMISP,TOUT,RTCD,EMI,RADIN,RADSUM,FMA,FM,SCFM,
     2 FXFU,FDFU,TFUEL,WFNZ,FLO(40),TEMTM(40),H(40),FUEL(40),FUOX(40) ,
     3 UIN(40),TIN(40),FUELS(40),SEXIT,IGAM1(10),IGAM2(10)
      COMMON/TURB/NVK,NVD,C1,C2,CD,AK,DUIDXJ(3,3),AMFAC,ALFAC,
     1 MODEL,PR(13),PREF(13),PJAV(13),E
      COMMON/RAD/NVE,SIGMA,ABSOR,SCATR
      COMMON/REACT/ARCON1,PREXP1,CR1,ARCON2,PREXP2,CR2,MODER
      COMMON/DROPL/EVAP(192),NIP4,NFNZ,XD(3),YD(3),ZD(3),ALFA(3),
     1 BETA(3),DELTA(3),THETA1(3),THETA2(3),NSL(3),MFF(3),SMD(3),
     2 VFUEL(3),RFUEL(3),EVSU(64),NEVAP
      COMMON/INJEC/FLOWIN,IUINJ(20),JUINJ(20),UINJ(20),WUINJ(20),
     1 AUINJ(20),IUINJ(20),IVINJ(20),JVINJ(20),KVINJ(20),VINJ(20),
     2 EVINJ(20),DVINJ(20),AVINJ(20),TVINJ(20),NUINJ,NVINJ,JSW1,JSW2,
     3 USW,VSW,AFSW,FSW,TSW,WSW,SWNO,RHCSW
      IF (NTP.LE.0) GO TO 16
      IF (ISTEP.EQ.LASTEP) GO TO 11
      IF (MOD(ISTEP,IJUMP)) 20,11,20
   11 CONTINUE
      REWIND NTP
      READ (NTP) U,V,W,P
      CALL FPRINT (1,3,1)
      CALL FPRINT (5,5,4)
C ---- HERE PP IS ACTUALLY KE, P IS ACTUALLY DISSIPATION
      READ (NTP) PP,P
      DO 25 K=1,NP1
      DO 25 J=1,MP1
      KJM=KM(K)+JM(J)
      DO 25 I=1,LP1
      LP=KJM+I
   25 F(LP,NVD)=CD*F(LP,NVK)**1.5/(F(LP,NVD)+1.0E-30)
      CALL FPRINT (NVE,NVD,5)
C ------ HERE PP IS PHI, P IS MFU, DU IS MCC
      READ (NTP) PP,P,DU
      CALL FPRINT (NVFUOX,NVTE,7)
      CALL FPRINT (NVCO,NVCO,15)
      DO 50 K=1,NP1
      DO 50 J=1,MP1
      KJM=KM(K)+JM(J)
      DO 50 I=1,LP1
      LP=KJM+I
      FU9=F(LP,NVFUOX)-F(LP,NVFU)
      F(LP,NVCO2)=WCO2*CXX*FU9/WFU-WCO2*F(LP,NVCO)/WCO
      F(LP,NVOX)=RATIO1*F(LP,NVFU)+RATIO3*F(LP,NVCO)+RATIO2-
     1 (RATIO2+RATIO1)*F(LP,NVFUOX)
      F(LP,NVOX)=AMAX1(0.,F(LP,NVOX))
      F(LP,NVH2O)=HYY*WH2O*FU9/WFU/2.
      F(LP,NVN2)=1.-F(LP,NVFU)-F(LP,NVCO2)-F(LP,NVCO)-F(LP,NVOX)-
```

```
     1 F(LP,NVH2O)
   50 CONTINUE
      CALL FPRINT (NVH2O,NVNZ,16)
      IF (NFNZ.LE.0) GO TO 35
      DO 37 K=1,NP1
      DO 37 J=1,MP1
      KJM=KM(K)+JM(J)
      DO 37 I=1,LP1
      LP=KJM+I
   37 F(LP,NVFUOX)=0.
      DO 39 K=2,N
      DO 39 J=2,M
      KJM=KM(K)+JM(J)
      KJK=(K-2)*(MI-2)*(MJ-2)+(J-2)*(MI-2)
      DO 39 I=2,L
      LP=KJM+I
      LPC=KJK+(I-1)
   39 F(LP,NVFUOX)=EVAP(LPC)
      CALL FPRINT (NVFUOX,NVFUOX,22)
   35 CONTINUE
C -------- HERE DV IS ENTHALPY, DW IS FAV
      READ (NTP) DV,DW
      CALL FPRINT (NVH,NVFAV,10)
C -------- HERE U IS FX, V IS FY,  W IS FZ
      READ (NTP) U,V,W
      CALL FPRINT (NVRX,NVRZ,12)
C -------- RHO AND VISCOSITY
      CALL FPRINT (11,11,20)
      NV=4
      DO 56 K=1,NP1
      DO 56 J=1,MP1
      KJM=KM(K)+JM(J)
      DO 56 I=1,LP1
      LP=KJM+I
   56 F(LP,7)=0.
      CALL GAMMA
      CALL FPRINT (7,7,21)
      REWIND NTP1
      DO 46 II=1,2
   46 READ (NTP1)
C -------- HERE PP IS PHI, P IS MFU, DU IS MCO
      READ (NTP1) PP,P,DU
   16 CONTINUE
      WRITE(6,19)
   19 FORMAT (1H0,4HSTEP,5X,4HSMAX,7X,4HSSUM,6X,5HSEXIT,5X,
     1 6HP(2,M,2),3X,8HP(L,M,2),3X,8HU(I,J,K),3X,8HV(I,J,K),3X,
     2 8HW(I,J,K),3X,8HT(I,J,K),2X,10HRHO(I,J,K),2X,7HI  J  K)
   20 CONTINUE
      RETURN
      END
```

CARD NR.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
55	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
66	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
82	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
98	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
107	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.

```
      SUBROUTINE AUX                                                    AU        2
      COMMON F(3500),DU(500),DV(500),DW(500),                           COMFB     2
     1  RHO(500),VISC(500),SU(100),SP(100),DRHODP(500),                 COMFB     3
     1  AXP(100),AXM(100),AYP(100),AYM(100),AZP(100),                   COMFB     4
     2  AZM(100),CZ(100),CY(10),CZU(100),CYU(10),                       COMFB     5
     3  CZP(100),CYP(10),DIVG(100),NTP1,NTP2                            COMFB     6
      DIMENSION U(500),V(500),W(500),PP(500),P(500),TEMP(500)           COMFB     7
      DIMENSION GAM(500)                                                COMFB     8
      EQUIVALENCE (F(1),U(1)),(F(501),V(1)),(F(1001),W(1))              COMFB     9
      EQUIVALENCE (F(1501),PP(1)),(F(2001),P(1)),(F(2501),TEMP(1))      COMFB    10
      EQUIVALENCE (F(3001),GAM(1))                                      COMFB    11
      COMMON/CYL/R(30),RP(30),RMV(30),YSR(30),YSVR(30),IPLAX            COMMON    2
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),       COMMON    3
     1  YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),     COMMON    4
     2  FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME                         COMMON    5
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NT,NJ,NK,NINJ,NINJNF,NV, COMMON    6
     1  NNV,NGOTO,K,ISTR,JSTR,KSTR,NVP(20),KM(30),JM(30),ISTEP,         COMMON    7
     2  ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISWP,JSWP,RELAX(16),NP,  COMMON    8
     3  NRHO,NGAM,IWLI(30,5),IWLO(30,5),JWLO(40,5),JWLI(40,5),IWEI,     COMMON    9
     4  IWEO,MM1,JWII,JWIO,JWOI,JWOO,IDW,JKIN(30,30),IKIN(40,30)        COMMON   10
      COMMON/INDEX/IPAR,LPREF,ISTOW,INCOMP,ITRAD,NVRX,NVRY,NVRZ,JPLANE  COMMON   11
     1  ,PLAXMI,LVK,LVD,LVFUOX,LVFU,LVCO,LVH,LVRK,LVRY,LVRZ,NVF(13),    COMMON   12
     2  IJUMP,IRES,TITLE2(20),IMAX,JMAX,KMAX,NVCO,FUMCO,NVH2O,NVCO2,    COMMON   13
     3  NVN2                                                            COMMON   14
      COMMON/THERM/NVH,NVFU,NVOX,NVFUOX,NVTE,MODEN,IDK,FSTOIC,HFU,CP,   COMMON   15
     1  GASCON,RHOCON,UNICON,PRESS,NVFAV,TCYLW,TINLW,TLIP,ACOEF(4),     COMMON   16
     2  T4,DFAC,WFU,WCO2,WCO,WOX,WH2O,WN2,HYY,CXX,RATIO1,RATIO2,        COMMON   17
     3  RATIO3,RATIO4,HCO,TAN,ITWALL                                    COMMON   18
      COMMON/CTOMA/NEND,ICTOMA(13)                                      COMMON   19
      COMMON/MIS/AMU,DEN,SMAX,SSUM,LASTEP,HTCEXT,CFR,EMISW,EMISIN,      COMGEN    2
     1  EMISR,TOUT,RTCO,EMI,RADIN,RADSUR,FMA,FK,SOFK,                   COMGEN    3
     2  FKFU,FOFU,TFUEL,WFNZ,FLD(40),TEMTM(40),H(40),FUEL(40),FUOX(40) ,COMGEN    4
     3  UIN(40),TIN(40),FUELS(40),SEXIT,IGAM1(10),IGAM2(10)             COMGEN    5
      COMMON/TURB/NVK,NVD,C1,C2,CD,AK,DUIDXJ(3,3),AKFAC,ALFAC,          COMGEN    6
     1  MODEL,PR(13),PREF(13),PJAY(13),E                                COMGEN    7
      COMMON/RAD/NVE,SIGMA,ABSOR,SCATR                                  COMGEN    8
      COMMON/REACT/ARCON1,PREXP1,CR1,ARCON2,PREXP2,CR2,MODER            COMGEN    9
      COMMON/DROPL/EVAP(192),NTRG,NFNZ,XD(3),YD(3),ZD(3),ALFA(3),       COMGEN   10
     1  BETA(3),DELTA(3),THETA1(3),THETA2(3),NSL(3),WFF(3),SMD(3),      COMGEN   11
     2  VFUEL(3),PFUEL(3),EVSJ(64),NEVAP                                COMGEN   12
      COMMON/INJEC/FLOWIN,IUINJ(20),JUINJ(20),UINJ(20),WUINJ(20),       COMGEN   13
     1  AUINJ(20),TUINJ(20),IVINJ(20),JVINJ(20),KVINJ(20),VINJ(20),     COMGEN   14
     2  EVINJ(20),DVINJ(20),AVINJ(20),TVINJ(20),NUINJ,NVINJ,JSW1,JSW2,  COMGEN   15
     3  USW,VSW,AFSW,FSW,TSW,WSW,SWNO,RHOSW                             COMGEN   16
      DIMENSION GENR(500),SUFU(500),SPFU(500),EDK(192)                  AU        6
C ------------- BEWARE OF EQUIVALENCE STATEMENTS -------------          AU        7
      EQUIVALENCE (GENR(1),DU(1)),(SUFU(1),DV(1)),(SPFU(1),DW(1))       AU        8
C -------------------------------------------------------------------   AU        9
      ENTRY DENS                                                        AU       10
      RELAXR=1.-RELAX(NRHO)                                             AU       11
      KONTRO=2                                                          AU       12
      IF (ISTEP.EQ.0) KONTRO=1                                          AU       13
      NVUE=8                                                            AU       14
      NVVE=9                                                            AU       15
      NVWE=10                                                           AU       16
      NVHP=7                                                            AU       17
      DO 1040 K=1,NP1                                                   AU       18
      DO 1040 J=1,MP1                                                   AU       19
      KJM=KM(K)+JM(J)                                                   AU       20
      DO 1040 I=1,LP1                                                   AU       21
      LP=KJM+I                                                          AU       22
      LPH=LP+NVM(NVH)                                                   AU       23
      LPHP=LP+NVM(NVHP)                                                 AU       24
 1040 F(LPHP)=F(LPH)                                                    AU       25
      GO TO (1034,1044,1034), MODEN                                     AU       26
 1044 DO 1050 K=1,NP1                                                   AU       27
      DO 1050 J=2,M                                                     AU       28
      KJM=KM(K)+JM(J)                                                   AU       29
      IS=IWLI(J,4)                                                      AU       30
      IE=IWLO(J,4)                                                      AU       31
      DO 1050 I=IS,IE                                                   AU       32
      LP=KJM+I                                                          AU       33
      LPHP=LP+NVM(NVHP)                                                 AU       34
      LPFU=LP+NVM(NVFU)                                                 AU       35
      LPCO=LP+NVM(NVCO)                                                 AU       36
      LPFUOX=LP+NVM(NVFUOX)                                             AU       37
      T=TEMP(LP)                                                        AU       38
```

```
      FUS=F(LPFUDI)-F(LPFU)
      FLPCO2=WCO2*CIN*FUS/WFU-WCO2*F(LPCO)/WCO
      FLPOX=RATIO1*F(LPFU)+RATIO3*F(LPCO)+RATIO2-(RATIO1+RATIO2)*
     1F(LPFUDI)
      FLPOX=AMAX1(FLPOX,0.)
      FLPH2O=HYY*WH2O*FUS/WFU/2.
      FLPN2=1.-F(LPFU)-FLPCO2-F(LPCO)-FLPOX-FLPH2O
      HPI=F(LPFU)*HOR(T,1)+FLPCO2*HOR(T,2)+F(LPCO)*HOR(T,3)+
     1     FLPOX*HOR(T,4)+FLPH2O*HOR(T,5)+FLPN2*HOR(T,12)
      CPI=F(LPFU)*CPOR(T,1)+FLPCO2*CPOR(T,2)+F(LPCO)*CPOR(T,3)+
     1     FLPOX*CPOR(T,4)+FLPH2O*CPOR(T,5)+FLPN2*CPOR(T,12)
      T=TEMP(LP)+(F(LPHP)-HPI)/CPI
      TEMP(LP)=(1.-RELAX(NVH))*TEMP(LP)+RELAX(NVH)*T
      PHI=F(LPFUDI)/FSTOIC
      TMAX=ACOEF(1)+PHI*(ACOEF(2)+PHI*(ACOEF(3)+PHI*ACOEF(4)))
      TMAX=AMAX1(TMAX,2000.)
      TEMP(LP)=AMIN1(TEMP(LP),TMAX)
 1050 TEMP(LP)=AMAX1(TEMP(LP),300.)
C ------ HERE DU IS U, DV IS V, DW IS W
 1034 REWIND NTPI
      READ (NTPI) DU,DV,DW,P
 1040 READ (NTPI)
C ------ HERE PP IS PHI, DU IS MFU, DV IS MCO
      READ (NTPI) PP,DU,DV
      REWIND NTPI
      READ (NTPI) U,V,W,P
      GO TO (1060,1062,1064), MODEN
 1060 DO 1061 K=1,NPI
      DO 1061 J=1,NPJ
      KJ=NKM(K)+JM(J)
      IS=IWLI(J,5)
      IE=IWLO(J,5)
      DO 1061 I=IS,IE
      LP=KJ+I
      RHO(LP)=DEN
 1061 CONTINUE
      GO TO 1200
 1062 DO 1063 K=1,NPI
      DO 1063 J=1,NPJ
      KJ=NKM(K)+JM(J)
      IS=IWLI(J,5)
      IE=IWLO(J,5)
      DO 1063 I=IS,IE
      LP=KJ+I
      LPTE=LP+NVM(NVTE)
      LPFUDI=LP+NVM(NVFUDI)
C ------ CAUTION HERE
      LPFU=LP+NVM(NVFU+1)
      LPCO=LP+NVM(NVCO+1)
      FUS=F(LPFUDI)-F(LPFU)
      FLPH2O=HYY*WH2O*FUS/WFU/2.
      FLPCO2=WCO2*CIN*FUS/WFU-WCO2*F(LPCO)/WCO
      FLPOX=RATIO1*F(LPFU)+RATIO3*F(LPCO)+RATIO2-(RATIO2+RATIO1)*
     2F(LPFUDI)
      FLPOX=AMAX1(FLPOX,0.)
      FLPN2=1.-F(LPFU)-FLPCO2-F(LPCO)-FLPOX-FLPH2O
 1009 CONTINUE
      FLPTE=F(LPTE)
      FLPTE=AMAX1(FLPTE,100.)
      WMIX=F(LPFU)/WFU+FLPCO2/WCO2+F(LPCO)/WCO+FLPOX/WOX+FLPH2O/WH2O+
     1   FLPN2/WN2
      DENST=RHOCON/(WMIX*FLPTE)
      GO TO (1009,1010),KONTRO
 1009 RHO(LP)=DENST
 1010 RHO(LP)=RELAX(NRHO)*DENST+RELAXM*RHO(LP)
 1063 CONTINUE
 1064 CONTINUE
 1200 CONTINUE
      CALL DENMOD
      RETURN
C ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** *
      ENTRY VISCO
C ------ HERE DU IS VE, DV IS DISS
      READ (NTPI) DU,DV
      RELAXM=1.-RELAX(NGAM)
      KONTRO=2
      IF (ISTEP.EQ.IPES) KONTRO=1
```

```
      DO 2000 K=1,MP1
      DO 2000 J=2,M
      KJM=KM(K)+JM(J)
      IS=IWLI(J,4)
      IE=IWLO(J,4)
      DO 2000 I=IS,IE
      LP=KJM+I
      GO TO (2001,2002),MODEL
 2001 CONTINUE
      VISC(LP)=AMU
      GO TO 2000
 2002 CONTINUE
      LPK=LP+NVM(NVK+4)
      LPD=LP+NVM(NVD+4)
      VISCOS=RHO(LP)*CD*F(LPK)**2/(F(LPD)+1.E-30)
      GO TO (2003,2004),KONTRO
 2003 VISC(LP)=VISCOS
 2004 VISC(LP)=RELAX(NGAM)*VISCOS+RELAXM*VISC(LP)
 2000 CONTINUE
C ------- CALCULATE YPLUS
      DO 2020 K=1,MP1
      DO 2022 I=1,LP1
      J=JWLO(I,4)
      LP=KM(K)+JM(J)+I
      LPK=LP+NVM(NVK+4)
      DIST=.5*YDIF(J)
      IF (J.EQ.MP1) DIST=YDIF(MP1)
      YPLUS=RHO(LP-NI)*SQRT(F(LPK-NI)*RTCD)*DIST/AMU
      VISC(LP)=YPLUS
      J=JWLI(I,4)
      LP=KM(K)+JM(J)+I
      LPK=LP+NVM(NVK+4)
      DIST=.5*YDIF(J+1)
      IF (J.EQ.1) DIST=YDIF(2)
      YPLUS=RHO(LP+NI)*SQRT(F(LPK+NI)*RTCD)*DIST/AMU
      VISC(LP)=YPLUS
 2022 CONTINUE
      DO 2024 J=2,M
      I=IWLI(J,4)-1
      LP=KM(K)+JM(J)+I
      LPK=LP+NVM(NVK+4)
      DIST=.5*XDIF(I+1)
      IF (I.EQ.1) DIST=XDIF(2)
      YPLUS=RHO(LP+1)*SQRT(F(LPK+1)*RTCD)*DIST/AMU
      VISC(LP)=YPLUS
      I=IWLO(J,4)+1
      LP=KM(K)+JM(J)+I
      LPK=LP+NVM(NVK+4)
      DIST=.5*XDIF(I)
      IF (I.EQ.LP1) DIST=XDIF(LP1)
      YPLUS=RHO(LP-1)*SQRT(F(LPK-1)*RTCD)*DIST/AMU
      VISC(LP)=YPLUS
 2024 CONTINUE
 2020 CONTINUE
      DO 3005 K=2,N
      DO 3005 J=2,M
      KJM=KM(K)+JM(J)
      IS=IWLI(J,4)
      IE=IWLO(J,4)
      DO 3005 I=IS,IE
      LP=KJM+I
      LPK=LP+NVM(NVK+4)
      LPD=LP+NVM(NVD+4)
      LPC=I-1+(J-2)*(NI-2)+(K-2)*(NI-2)*(NJ-2)
 3005 EDK(LPC)=F(LPD)/(F(LPK)+1.E-30)
      RETURN
C  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **
      ENTRY GAMMA
      DO 3000 K=1,MP1
      DO 3000 J=2,M
      KJM=KM(K)+JM(J)
      IS=IWLI(J,4)
      IE=IWLO(J,4)
      DO 3000 I=IS,IE
      LP=KJM+I
      GO TO (3001,3002),MODEL
 3001 CONTINUE
```

```
      GAM(LP)=VISC(LP)/PE(NV)
      GO TO 3005
 3002 CONTINUE
      GAM(LP)=VISC(LP)/PREF(NV)
 3003 CONTINUE
      CALL GAMDS
 3004 CONTINUE
      RETURN
C  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **
      ENTRY SOURCE
CAUTION NOT ALL SOURCE TERMS ARE VALID - AT BOUNDARY NODES -
CHECK AND MODIFY ACCORDINGLY IN SGMOD
      GO TO (100,200,300,400),NGOTO
C ------------------  SOURCE TERMS FOR U-VELOCITY   ------------------
100   DO 101 J=2,M
      IS=IML1(J,NGOTO)
      IE=IML3(J,NGOTO)
      DO 101 I=IS,IE
      LIJ=JM(J)+I
      LP=LIJ+KM(K)
      LXP=LP+1
      LXM=LP-1
      DUDXP=(U(LXP)-U(LP))/XS(I)
      DUDXM=(U(LP)-U(LXM))/XS(I-1)
      GAMLP=GAM(LP)
      GAMLXM=GAM(LXM)
      IF (I.EQ.IS) GAMLXM=GAM(LXM-1)
      IF (I.EQ.IE) GAMLP=GAM(LP+1)
      SU(LIJ)=(GAMLP*DUDXP-GAMLXM*DUDXM)/XSU(I)
      LYP=LP+NI
      LYM=LP-NI
      LYP1=LYP-1
      LYM1=LYM-1
      GAMP=0.25*(GAM(LP)+GAM(LXM)+GAM(LYP)+GAM(LYP1))
      GAMM=0.25*(GAM(LP)+GAM(LXM)+GAM(LYM)+GAM(LYM1))
      DVDXP=(V(LYP)-V(LYP1))/XDIF(I)
      DVDXM=(V(LP)-V(LXM))/XDIF(I)
      SU(LIJ)=SU(LIJ)+(GAMP*DVDXP*RR(J+1)-GAMM*DVDXM*RR(J))/YSR(J)
      LZP=LP+NINJ
      LZM=LP-NINJ
      LZP1=LZP-1
      LZM1=LZM-1
      GAMP=0.25*(GAM(LP)+GAM(LXM)+GAM(LZP)+GAM(LZP1))
      GAMM=0.25*(GAM(LP)+GAM(LXM)+GAM(LZM)+GAM(LZM1))
      DWDXP=(W(LZP)-W(LZP1))/XDIF(I)
      DWDXM=(W(LP)-W(LXM))/XDIF(I)
      SU(LIJ)=SU(LIJ)+(GAMP*DWDXP-GAMM*DWDXM)*YS(J)/YSR(J)/ZS(K)
      SP(LIJ)=0.
101   CONTINUE
      GO TO 5000
C ------------------  SOURCE TERMS FOR V-VELOCITY   ------------------
200   DO 201 J=3,M
      IS=IML1(J,NGOTO)
      IE=IML3(J,NGOTO)
      DO 201 I=IS,IE
      LIJ=JM(J)+I
      LP=LIJ+KM(K)
      LYP=LP+NI
      LYM=LP-NI
      DVDYP=(V(LYP)-V(LP))/YS(J)
      DVDYM=(V(LP)-V(LYM))/YS(J-1)
      GAMLP=GAM(LP)
      GAMLYM=GAM(LYM)
      IF (J.EQ.JML1(I,NGOTO)+1) GAMLYM=GAM(LYM-NI)
      IF (J.EQ.JML3(I,NGOTO)-1) GAMLP=GAM(LP+NI)
      SU(LIJ)=(GAMLP*DVDYP*RRV(J+1)-GAMLYM*DVDYM*RRV(J))/YSVR(J)
      LXP=LP+1
      LXM=LP-1
      LXP1=LXP-NI
      LXM1=LXM-NI
      GAMP=0.25*(GAM(LP)+GAM(LYM)+GAM(LXP)+GAM(LXP1))
      GAMM=0.25*(GAM(LP)+GAM(LYM)+GAM(LXM)+GAM(LXM1))
      DUDYP=(U(LXP)-U(LXP1))/YDIF(J)
      DUDYM=(U(LP)-U(LYM))/YDIF(J)
      SU(LIJ)=SU(LIJ)+(GAMP*DUDYP-GAMM*DUDYM)/XS(I)
      LZP=LP+NINJ
      LZM=LP-NINJ
```

```
      LZP1=LZP-NI                                                       AU 270
      LZM1=LZM-NI                                                       AU 271
      GAMP=0.25*(GAM(LP)+GAM(LYP)+GAM(LZP)+GAM(LZP1))                   AU 272
      GAMM=0.25*(GAM(LP)+GAM(LYM)+GAM(LZM)+GAM(LZM1))                   AU 273
      DWDYP=(W(LZP)-W(LZP1))/YDIF(J)                                    AU 274
      DWDYM=(W(LP)-W(LYM))/YDIF(J)                                      AU 275
      SU(LIJ)=SU(LIJ)+(GAMP*DWDYP-GAMM*DWDYM)*YSV(J)/YSVR(J)/ZS(K)      AU 276
      WMM=0.5*(W(LP)+W(LYM))                                            AU 277
      WMP=0.5*(W(LZP)+W(LZP1))                                          AU 278
      SU(LIJ)=SU(LIJ)+PLAXM1*(GAMM*WMM-GAMP*WMP)*YSV(J)/YSVR(J)/ZS(K)/  AU 279
     1RM(J)                                                             AU 280
      GAMPTZ=GAM(LP)+GAM(LYP)                                           AU 281
      SU(LIJ)=SU(LIJ)+PLAXM1*GAMPTZ*(WMMM-WMMP)/DM(J)/ZS(K)/RM(J)       AU 282
      SP(LIJ)=-GAMPTZ/RM(J)/RP(J)*PLAXM1                                AU 283
  201 CONTINUE                                                          AU 284
      GO TO 9030                                                        AU 285
C ---------------- SOURCE TERMS FOR W-VELOCITY   ---------------        AU 286
  300 DO 301 J=2,M                                                      AU 287
      IS=IWL1(J,NGCT2)                                                  AU 288
      IE=IWL3(J,NGCT2)                                                  AU 289
      DO 301 I=IS,IE                                                    AU 290
      LIJ=JM(J)+I                                                       AU 291
      LP=LIJ+KM(K)                                                      AU 292
      LZP=LP+NIMJ                                                       AU 293
      IF (K.EQ.MP1) LZP=LIJ+KM(3)                                       AU 294
      LZM=LP-NIMJ                                                       AU 295
      DWDZP=(W(LZP)-W(LP))/ZS(K)                                        AU 296
      DWDZM=(W(LP)-W(LZM))/ZS(K-1)                                      AU 297
      GAMLP=GAM(LP)                                                     AU 298
      GAMLZM=GAM(LZM)                                                   AU 299
      IF(K.EQ.3) GAMLZM=GAM(LZM-NIMJ)                                   AU 300
      SU(LIJ)=(GAMLP*DWDZP-GAMLZM*DWDZM)/R(J) /YSR(J)/ZSW(K)*YS(J)      AU 301
      LXP=LP+1                                                          AU 302
      LXM=LP-1                                                          AU 303
      LXP1=LXP-NIMJ                                                     AU 304
      LXM1=LXM-NIMJ                                                     AU 305
      GAMP=0.25*(GAM(LP)+GAM(LZM)+GAM(LXP)+GAM(LXP1))                   AU 306
      GAMM=0.25*(GAM(LP)+GAM(LZM)+GAM(LXM)+GAM(LXM1))                   AU 307
      DUDZP=(U(LXP)-U(LXP1))/ZDIF(K)                                    AU 308
      DUDZM=(U(LP)-U(LZM1))/ZDIF(K)                                     AU 309
      SU(LIJ)=SU(LIJ)+(GAMP*DUDZP-GAMM*DUDZM)/XS(I)/R(J)                AU 310
      LYP=LP+NI                                                         AU 311
      LYM=LP-NI                                                         AU 312
      LYP1=LYP-NIMJ                                                     AU 313
      LYM1=LYM-NIMJ                                                     AU 314
      GAMP=0.25*(GAM(LP)+GAM(LZM)+GAM(LYP)+GAM(LYP1))                   AU 315
      GAMM=0.25*(GAM(LP)+GAM(LZM)+GAM(LYM)+GAM(LYM1))                   AU 316
      DVDZP=(V(LYP)-V(LYP1))/ZDIF(K)                                    AU 317
      DVDZM=(V(LP)-V(LZM1))/ZDIF(K)                                     AU 318
      SU(LIJ)=SU(LIJ)+(GAMP*DVDZP-GAMM*DVDZM)/YSR(J)                    AU 319
      WMM=0.5*(W(LP)+W(LYM))                                            AU 320
      WMP=0.5*(W(LP)+W(LYP))                                            AU 321
      SU(LIJ)=SU(LIJ)+PLAXM1*(GAMM*WMM-GAMP*WMP)/YSR(J)                 AU 322
      VPTZ=V(LP)+V(LYP)                                                 AU 323
      VMTZ=V(LZM)+V(LZM+NI)                                             AU 324
      SU(LIJ)=SU(LIJ)+PLAXM1*(GAM(LP)*VPTZ-VMTZ*GAM(LZM))*YS(J)/R(J)/   AU 325
     1YSR(J)/ZSW(K)                                                     AU 326
      GAMP=0.5*(GAM(LP)+GAM(LZM))                                       AU 327
      SU(LIJ)=SU(LIJ)+PLAXM1*GAMP/R(J)*((WMMP-WMMM)/YS(J)+0.5*(VPTZ-VMTZ AU 328
     1)/R(J)/ZSW(K))                                                    AU 329
      SP(LIJ)=-GAMP/R(J)/R(J)*PLAXM1                                    AU 330
  301 CONTINUE                                                          AU 331
      GO TO 5000                                                        AU 332
C ------------ SOURCE TERMS FOR TURBULENT KINETIC ENERGY  ---------     AU 333
  400 CONTINUE                                                          AU 334
      IF (NG.NE.LUK) GO TO 500                                          AU 335
      DO 401 J=2,M                                                      AU 336
      IS=IWL1(J,NGCT2)                                                  AU 337
      IE=IWL3(J,NGCT2)                                                  AU 338
      DO 401 I=IS,IE                                                    AU 339
      MIN=JWL1(I,NGCT2)+1                                               AU 340
      MAX=JWL3(I,NGCT2)-1                                               AU 341
      LIJ=JM(J)+I                                                       AU 342
      LP=LIJ+KM(K)                                                      AU 343
      LXP=LP+1                                                          AU 344
      LYP=LP+NI                                                         AU 345
      LZP=LP+NIMJ                                                       AU 346
```

```
      LXM=LP-1
      LYM=LP-NI
      LZM=LP-NINJ
      LPPP=LYP+1
      LPMP=LYM+1
      LPPM=LZM+1
      LPMP=LZP+1
      LMPO=LXM+NI
      LMPP=LZP+NI
      LMPM=LZM+NI
      LMOP=LXM+NINJ
      LMMP=LYM+NINJ
C     CALCULATE THE PRODUCTION TERM
      DUIDXJ(1,1)=(U(LXP)-U(LP))/XS(I)
      DUIDXJ(2,2)=(V(LYP)-V(LP))/YS(J)
      DUIDXJ(3,3)=(W(LZP)-W(LP))/ZS(K)/R(J)
     1 +(0.5*(V(LP)+V(LYP))/R(J))
      IF (I-IS) 411,412,411
  411 VXM=0.5*(V(LXM)+V(LMPO))
      WXM=0.5*(W(LXM)+W(LMOP))
      XM=X(I-1)
      GO TO 413
  412 VXM=0.5*(V(LP)+V(LYP))
      WXM=0.5*(W(LP)+W(LZP))
      XM=X(I)
  413 IF (I-IE) 414,415,414
  414 VXP=0.5*(V(LXP)+V(LPPO))
      WXP=0.5*(W(LXP)+W(LPOP))
      XP=X(I+1)
      GO TO 416
  415 VXP=0.5*(V(LP)+V(LYP))
      WXP=0.5*(W(LP)+W(LZP))
      XP=X(I)
  416 DX=XP-XM
      DUIDXJ(2,1)=(VXP-VXM)/DX
      DUIDXJ(3,1)=(WXP-WXM)/DX
      IF (J-MIN) 421,422,421
  421 UYM=0.5*(U(LYM)+U(LPMO))
      WYM=.5*(W(LYM)+W(LPMO))
      YM=Y(J-1)
      GO TO 423
  422 UYM=0.5*(U(LP)+U(LXP))
      WYM=0.5*(W(LP)+W(LZP))
      YM=Y(J)
  423 IF (J-MAX) 424,425,424
  424 UYP=0.5*(U(LYP)+U(LPPO))
      WYP=0.5*(W(LYP)+W(LOPP))
      YP=Y(J+1)
      GO TO 426
  425 UYP=0.5*(U(LP)+U(LXP))
      WYP=0.5*(W(LP)+W(LZP))
      YP=Y(J)
  426 DY=YP-YM
      DUIDXJ(3,2)=(WYP-WYM)/DY-PLAXM1*0.5*(W(LP)+W(LZP))/R(J)
      DUIDXJ(1,2)=(UYP-UYM)/DY
      IF(K-2) 431,432,431
  431 UZM=0.5*(U(LZM)+U(LPOM))
      VZM=0.5*(V(LZM)+V(LOPM))
      ZM=Z(K-1)
      GO TO 433
  432 UZM=0.5*(U(LP)+U(LXP))
      VZM=0.5*(V(LP)+V(LYP))
      ZM=Z(K)
  433 IF(K-N) 434,435,434
  434 UZP=0.5*(U(LZP)+U(LPOP))
      VZP=0.5*(V(LZP)+V(LOPP))
      ZP=Z(K+1)
      GO TO 436
  435 UZP=0.5*(U(LP)+U(LXP))
      VZP=0.5*(V(LP)+V(LYP))
      ZP=Z(K)
  436 DZ=ZP-ZM
      DUIDXJ(1,3)=(UZP-UZM)/DZ/R(J)
      DUIDXJ(2,3)=(VZP-VZM)/DZ/R(J)
      SUM=0.
      DO 402 II=1,3
      DO 402 JJ=1,3
```

```
  402     SUM=SUM+(DUIDXJ(II,JJ)+DUIDXJ(JJ,II))*DUIDXJ(II,JJ)
          GEN(LP)=SUM
C         CALCULATE THE SOURCE TERM
          LPK=LP+NVR(NVK)
          LPD=LP+NVR(NVD)
          SU(LIJ)=RHO(LP)*CD*F(LPK)**2/(F(LPD)+1.E-30)*SUM
          SP(LIJ)=-RHO(LP)*F(LPD)/(F(LPK)+1.E-30)
          IF (I.GT.IS) GO TO 440
          IF (IKIN(J,K).EQ.1) GO TO 440
          DIST=.5*XDIF(2)
          IF (I.EQ.2) DIST=XDIF(2)
          VP=.5*SQRT((V(LP)+V(LYP))**2+(W(LP)+W(LZP))**2)
          TAUP=AMAX1(GAM(LXM)*VP/DIST,1.E-20)
          GAM(LXM)=0.
          VXP=V(LP)+V(LYP)+V(LXP)+V(LPPD)
          WXP=W(LP)+W(LZP)+W(LXP)+W(LPDP)
          VC=.25*SQRT(VXP**2+WXP**2)
          DVDY=VC/XS(I)
          SU(LIJ)=TAUP*DVDY
          SP(LIJ)=-RHO(LP)*RHO(LP)*CD*F(LPK)*DVDY/TAUP
  440     IF (I.LT.IE) GO TO 442
          IF (J.GT.JWOI.AND.J.LT.JWOO) GO TO 442
          DIST=.5*XDIF(I+1)
          IF (I.EQ.L) DIST=XDIF(LP1)
          VP=.5*SQRT((V(LP)+V(LYP))**2+(W(LP)+W(LZP))**2)
          TAUP=AMAX1(GAM(LXP)*VP/DIST,1.E-20)
          GAM(LXP)=0.
          VXM=V(LP)+V(LYP)+V(LXM)+V(LMPD)
          WXM=W(LP)+W(LZP)+W(LXM)+W(LMDP)
          VC=.25*SQRT(VXM**2+WXM**2)
          DVDY=VC/XS(I)
          SU(LIJ)=TAUP*DVDY
          SP(LIJ)=-RHO(LP)*RHO(LP)*CD*F(LPK)*DVDY/TAUP
  442     IF (J.GT.MIN) GO TO 444
          IF (ISW.EQ.0.OR.IKIN(I,K).EQ.1.OR.IKIN(I,K).EQ.3) GO TO 444
          DIST=.5*YDIF(J)
          IF (J.EQ.2) DIST=YDIF(2)
          VP=.5*SQRT((U(LP)+U(LXP))**2+(W(LP)+W(LZP))**2)
          TAUP=AMAX1(GAM(LYM)*VP/DIST,1.E-20)
          GAM(LYM)=0.
          UYP=U(LP)+U(LXP)+U(LYP)+U(LPPD)
          WYP=W(LP)+W(LZP)+W(LYP)+W(LGPP)
          VC=.25*SQRT(UYP**2+WYP**2)
          DVDY=VC/YS(J)
          SU(LIJ)=TAUP*DVDY
          SP(LIJ)=-RHO(LP)*RHO(LP)*CD*F(LPK)*DVDY/TAUP
  444     IF (J.LT.MAX) GO TO 401
          IF (IKIN(I,K).EQ.2.OR.IKIN(I,K).EQ.3) GO TO 401
          DIST=.5*YDIF(J+1)
          IF (J.EQ.M) DIST=YDIF(MP1)
          VP=.5*SQRT((U(LP)+U(LXP))**2+(W(LP)+W(LZP))**2)
          TAUP=AMAX1(GAM(LYP)*VP/DIST,1.E-20)
          GAM(LYP)=0.
          UYM=U(LP)+U(LXP)+U(LYM)+U(LPMD)
          WYM=W(LP)+W(LZP)+W(LYM)+W(LDMP)
          VC=.25*SQRT(UYM**2+WYM**2)
          DVDY=VC/YS(J)
          SU(LIJ)=TAUP*DVDY
          SP(LIJ)=-RHO(LP)*RHO(LP)*CD*F(LPK)*DVDY/TAUP
  401     CONTINUE
          GO TO 5000
C +-+-+-+-+-+-   SOURCE TERMS FOR TURBULENCE DISSIPATION  +-+-+-+-+-+-
  500     CONTINUE
          IF (NV.NE.LVD) GO TO 600
          DO 501 J=2,M
          IS=IWLI(J,NGOTO)
          IE=IWLO(J,NGOTO)
          DO 501 I=IS,IE
          LIJ=JR(J)+I
          LP=LIJ+KR(K)
          LPK=LP+NVR(NVK)
          LPD=LP+NVR(NVD)
          SU(LIJ)=C1*CD*RHO(LP)*F(LPK)*GEN(LP)
          SP(LIJ)=-C2*RHO(LP)*F(LPD)/(F(LPK)+1.E-30)
  501     CONTINUE
          GO TO 5000
C +-+-+-+-+-+-+-+-   SOURCE TERMS FOR FUEL   +-+-+-+-+-+-+-+-+-+-+-+-
```

```
      600 CONTINUE                                                        AU    501
          IF (NV.NE.LVFU) GO TO 700                                       AU    502
          DO 601 J=2,M                                                    AU    503
          IS=IWLI(J,NGOTO)                                                AU    504
          IE=IWLO(J,NGOTO)                                                AU    505
          DO 601 I=IS,IE                                                  AU    506
          LIJ=JM(J)+I                                                     AU    507
          LP=LIJ+KM(K)                                                    AU    508
          LPC=I-1+(J-2)*(NI-2)+(K-KSTR)*(NI-2)*(NJ-2)                     AU    509
          LPFU=LP+NVM(NVFU)                                               AU    510
          LPFUOX=LP+NVM(NVFUOX)                                           AU    511
          LPTE=LP+NVM(NVTE)                                               AU    512
          FLPTE=F(LPTE)                                                   AU    513
          FLPTE=AMAX1(FLPTE,100.)                                         AU    514
          F(LPFU)=AMIN1(F(LPFU),F(LPFUOX))                                AU    515
          LPCO=LP+NVM(NVCO)                                               AU    516
          FLPOX=RATIO1*F(LPFU)+RATIO3*F(LPCO)+RATIO2-(RATIO2+RATIO1)*     AU    517
         2F(LPFUOX)                                                       AU    518
          FLPOX=AMAX1(FLPOX,0.)                                           AU    519
          RHOLP=ABS(RHO(LP))                                              AU    520
          SOR1=-PREXP1*RHOLP**1.5*SQRT(F(LPFU))*FLPOX*EXP(-ARCON1/FLPTE)  AU    521
          GO TO (611,612),MODER                                           AU    522
      611 SOR=SOR1                                                        AU    523
          GO TO 602                                                       AU    524
      612 LPK=LP+NVM(NVK)                                                 AU    525
          LPD=LP+NVM(NVD)                                                 AU    526
          PHI=AMIN1(F(LPFU),FLPOX/RATIO1)                                 AU    527
          SOR2=-CR1*PHI*RHO(LP)*EDK(LPC)                                  AU    528
          SOR=AMAX1(SOR1,SOR2)                                            AU    529
      602 FUB=AMAX1(0.,((RATIO2+RATIO1)*F(LPFUOX)-RATIO2-RATIO3*F(LPCO))/ AU    530
         2RATIO1)                                                         AU    531
          FUO=.5*(F(LPFU)+FUB)                                            AU    532
          DSDFU=SOR/(F(LPFU)-FUO+1.E-30)                                  AU    533
          SU(LIJ)=SOR-DSDFU*F(LPFU)                                       AU    534
          SP(LIJ)=DSDFU                                                   AU    535
          SUFU(LP)=SU(LIJ)                                                AU    536
          SPFU(LP)=SP(LIJ)                                                AU    537
      601 CONTINUE                                                        AU    538
          GO TO 5000                                                      AU    539
C +-+-+-+-+-+-+-+-+-+-   SOURCE TERMS FOR ENTHALPY   +-+-+-+-+-+-+-+-+-+-  AU    540
      700 CONTINUE                                                        AU    541
          IF (NV.NE.LVH) GO TO 800                                        AU    542
          DO 701 J=2,M                                                    AU    543
          IS=IWLI(J,NGOTO)                                                AU    544
          IE=IWLO(J,NGOTO)                                                AU    545
          DO 701 I=IS,IE                                                  AU    546
          LIJ=JM(J)+I                                                     AU    547
          SU(LIJ)=0.                                                      AU    548
          SP(LIJ)=0.                                                      AU    549
          GO TO (701,702),ITPAB                                           AU    550
      702 CONTINUE                                                        AU    551
          LP=LIJ+KM(K)                                                    AU    552
          LPH=LP+NVM(NVH)                                                 AU    553
          LPFAV=LP+NVM(NVFAV)                                             AU    554
          LPTE=LP+NVM(NVTE)                                               AU    555
          FLPTE=F(LPTE)                                                   AU    556
          FLPE=SIGMA*FLPTE**4                                             AU    557
          FAV=F(LPFAV)                                                    AU    558
          SOR=4.*ABSOR*(FAV-FLPE)                                         AU    559
          TO=(FAV/SIGMA)**.25                                             AU    560
          TO=TO+.001                                                      AU    561
          DSDH=SOR/(CP*(FLPTE-TO))                                        AU    562
          SU(LIJ)=SU(LIJ)+SOR-DSDH*F(LPH)                                 AU    563
          SP(LIJ)=SP(LIJ)+DSDH                                            AU    564
      701 CONTINUE                                                        AU    565
          GO TO 5000                                                      AU    566
C +-+-+-+-+-+-+-+-+-+-+-+-   SOURCE TERMS FOR PHI   +-+-+-+-+-+-+-+-+-+-+-  AU    567
      800 CONTINUE                                                        AU    568
          IF (NV.NE.LVFUOX) GO TO 900                                     AU    569
          DO 801 J=2,M                                                    AU    570
          IS=IWLI(J,NGOTO)                                                AU    571
          IE=IWLO(J,NGOTO)                                                AU    572
          DO 801 I=IS,IE                                                  AU    573
          LIJ=JM(J)+I                                                     AU    574
          SU(LIJ)=0.                                                      AU    575
          SP(LIJ)=0.                                                      AU    576
      801 CONTINUE                                                        AU    577
```

```
      GO TO 5000                                                        AU   578
C----------------------    SOURCE TERM FOR CO    ---------------------- AU   579
  900 IF(NY.NE.LVCO) GO TO 1900                                         AU   580
      DO 901 J=2,M                                                      AU   581
      IS=IWLI(J,NGOTO)                                                  AU   582
      IE=IWLO(J,NGOTO)                                                  AU   583
      DO 901 I=IS,IE                                                    AU   584
      LIJ=JM(J)+I                                                       AU   585
      LP=LIJ+KM(K)                                                      AU   586
      LPC=I-1+(J-2)*(MI-2)+(K-KSTR)*(MI-2)*(MJ-2)                       AU   587
      LPCO=LP+NVM(NVCO)                                                 AU   588
      LPFUOX=LP+NVM(NVFUOX)                                             AU   589
      LPFU=LP+NVM(NVFU)                                                 AU   590
      LPTE=LP+NVM(NVTE)                                                 AU   591
      FLPTE=F(LPTE)                                                     AU   592
      FLPTE=AMAX1(FLPTE,100.)                                           AU   593
      F(LPCO)=AMIN1(F(LPCO),RATIO4*(F(LPFUOX)-F(LPFU)))                 AU   594
      FLPOX=RATIO1*F(LPFU)+RATIO3*F(LPCO)+RATIO2-(RATIO2+RATIO1)*       AU   595
     2F(LPFUOX)                                                         AU   596
      FLPOX=AMAX1(FLPOX,0.)                                             AU   597
      SOR3=-PREEXP2*DHC(LP)**2*F(LPCO)*FLPOX*EXP(-ARCON2/FLPTE)         AU   598
      GO TO (911,912),MODES                                             AU   599
  911 SORCO=SOR3                                                        AU   600
      GO TO 902                                                         AU   601
  912 CONTINUE                                                          AU   602
      PHI=AMIN1(F(LPCO),FLPOX/RATIO3)                                   AU   603
      SOR4=-CR2*PHI*RHO(LP)*EDK(LPC)                                    AU   604
      SORCO=AMAX1(SOR3,SOR4)                                            AU   605
  902 FUB=AMAX1(0.,((RATIO2+RATIO1)*F(LPFUOX)-RATIO2-RATIO1*F(LPFU))/   AU   606
     2RATIO3)                                                           AU   607
      FUB=.5*(F(LPCO)+FUB)                                              AU   608
      DSDCO=SORCO/(F(LPCO)-FUB+1.E-30)                                  AU   609
      SU(LIJ)=SORCO-DSDCO*F(LPCO)-RATIO4*(SUFU(LP)+SPFU(LP)*F(LPFU))    AU   610
      SP(LIJ)=DSDCO                                                     AU   611
  901 CONTINUE                                                          AU   612
 1900 CONTINUE                                                          AU   613
C  COME HERE TO INTRODUCE FALSE INERTIA                                 AU   614
 5000 CONTINUE                                                          AU   615
      RETURN                                                            AU   616
      END                                                               AU   617
```

CARD NR.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
57	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
65	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
86	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
104	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
105	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
115	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
148	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
155	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
162	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
170	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
175	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
209	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
223	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
230	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
561	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
599	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
638	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.

```
      FUNCTION GASP (TT,I)
      DIMENSION AH(7,12),AL(7,12),W(12)
C
C     SPECIES ORDER - FUEL,CO2,CO,O2,H2O,OH,O,H,H2,N,NO,N2
C
      DATA ((AH(I,J),I=1,7),J=1,6)/
     1 0.25545935E+02, 0.46470055E-01,-0.22957813E-04, 0.49494616E-08,
     2-0.37030219E-12,-0.40857112E+05, 0.                            ,
     3  .44608641E+01,  .30981719E-02, -.12392571E-05,  .22741325E-09,
     4 -.15525954E-13, -.48961442E+05, -.98632982E+00,
     5  .29840696E+01,  .14891390E-02, -.57899684E-06,  .10364577E-09,
     6 -.69353550E-14, -.14245228E+05,  .63479156E+01,
     7  .36219535E+01,  .73618264E-03, -.19652228E-06,  .36201558E-10,
     8 -.28945627E-14, -.12019825E+04,  .36150960E+01,
     9  .27167633E+01,  .29451374E-02, -.80224374E-06,  .10226682E-09,
     * -.48472145E-14, -.29905826E+05,  .66305671E+01,
     1  .29131230E+01,  .95418248E-03, -.19086325E-06,  .12730795E-10,
     2  .24939741E-15,  .39647060E+04,  .54208735E+01/
C
      DATA ((AH(I,J),I=1,7),J=7,12)/
     1  .25423595E+01, -.27550619E-04, -.31028033E-08,  .45510474E-11,
     2 -.43680515E-15,  .29230803E+05,  .49203080E+01,
     3  .25000000E+01, 0.            , 0.            , 0.            ,
     4 0.            ,  .25471627E+05, -.46011763E+00,
     5  .31001901E+01,  .51119464E-03,  .52644210E-07, -.34909973E-10,
     6  .36945345E-14, -.87738042E+03, -.19629421E+01,
     7  .24502652E+01,  .10661458E-03, -.74653337E-07,  .18796524E-10,
     8 -.10259839E-14,  .56116040E+05,  .44487581E+01,
     9  .31890000E+01,  .13382281E-02, -.52899318E-06,  .95919332E-10,
     * -.64847932E-14,  .98283290E+04,  .67458126E+01,
     1  .28963194E+01,  .15154866E-02, -.57235277E-06,  .99807393E-10,
     2 -.65223555E-14, -.90586184E+03,  .61615148E+01/
C
      DATA ((AL(I,J),I=1,7),J=1,6)/
     1 0.57793475E+01, 0.50561468E-01, 0.51144255E-04,-0.34088140E-07,
     2 0.39503975E-10,-0.29323482E+05, 0.                            ,
     3  .24007797E+01,  .87350957E-02, -.66070878E-05,  .20021861E-08,
     4  .63274039E-15, -.48377527E+05,  .96951457E+01,
     5  .37100928E+01, -.16190964E-02,  .35923594E-05, -.20319674E-08,
     6  .23953344E-12, -.14356310E+05,  .29555351E+01,
     7  .36255985E+01, -.18782184E-02,  .70554544E-05, -.67635137E-08,
     8  .21555993E-11, -.10475226E+04,  .43052778E+01,
     9  .40701275E+01, -.11084499E-02,  .41521180E-05, -.29637404E-08,
     *  .80702103E-12, -.30279722E+05, -.32270046E+00,
     1  .39365518E+01, -.10702214E-02,  .96549757E-06,  .19713972E-09,
     2 -.22571094E-12,  .36412923E+04,  .49370009E+00/
C
      DATA ((AL(I,J),I=1,7),J=7,12)/
     1  .29464287E+01, -.16381665E-02,  .24210316E-05, -.16028432E-08,
     2  .38906964E-12,  .29147644E+05,  .29639949E+01,
     3  .25000000E+01, 0.            , 0.            , 0.            ,
     4 0.            ,  .25471627E+05, -.46011762E+00,
     5  .30574451E+01,  .26765260E-02, -.58099162E-05,  .55210391E-08,
     6 -.18122739E-11, -.98890474E+03, -.22997056E+01,
     7  .25033714E+01, -.21800181E-04,  .54205297E-07, -.56475603E-10,
     8  .20999044E-13,  .56098904E+05,  .41675764E+01,
     9  .40459521E+01, -.34181783E-02,  .79819109E-05, -.61139316E-08,
     *  .15919076E-11,  .97453934E+04,  .29974988E+01,
     1  .36748261E+01, -.12081500E-02,  .23240102E-05, -.63217559E-09,
     2 -.22577253E-12, -.10611559E+04,  .23580424E+01/
C
      DATA W/54.,44.,28.,32.,18.,17.,16.,1.,2.,14.,30.,28./,KOUNT/0/
      DATA TLIM/1500./
C     ****************************************************************
      ENTRY GHT
      T=TT
      IF (T.LT.1000.) GO TO 10
      ARG=AH(1,I)*(1.-ALOG(T))+AH(6,I)/T-(AH(7,I)+T*(AH(2,I)/2.+T*(AH(3,
     1I)/6.+T*(AH(4,I)/12.+T*AH(5,I)/20.))))
      GO TO 15
   10 ARG=AL(1,I)*(1.-ALOG(T))+AL(6,I)/T-(AL(7,I)+T*(AL(2,I)/2.+T*(AL(3,
     1I)/6.+T*(AL(4,I)/12.+T*AL(5,I)/20.))))
   15 GASP=ARG
      RETURN
C     ****************************************************************
      ENTRY GPDP
      T=TT
```

```
      IF (I.EQ.1) T=AMIN1(T,TLIM)
      IF (T.LT.1000.) GO TO 20
      ARG=AM(1,I)+T*(AM(2,I)+T*(AM(3,I)+T*(AM(4,I)+T*AM(5,I))))
      GO TO 25
   20 ARG=AL(1,I)+T*(AL(2,I)+T*(AL(3,I)+T*(AL(4,I)+T*AL(5,I))))
   25 GASP=ARG*1.987*4184./W(I)
      RETURN
C     ******************************************************************
      ENTRY HBR
      T=TT
      IF (I.EQ.1) T=AMIN1(T,TLIM)
      IF (T.LT.1000.) GO TO 30
      ARG=AM(6,I)+T*(AM(1,I)+T*(AM(2,I)/2.+T*(AM(3,I)/3.+T*(AM(4,I)/4.+T
     1*AM(5,I)/5))))
      GO TO 35
   30 ARG=AL(6,I)+T*(AL(1,I)+T*(AL(2,I)/2.+T*(AL(3,I)/3.+T*(AL(4,I)/4.+T
     1*AL(5,I)/5))))
   35 GASP=ARG*1.987*4184./W(I)
      IF (TT.LT.TLIM.OR.I.NE.1) RETURN
      CPI=AM(1,I)+T*(AM(2,I)+T*(AM(3,I)+T*(AM(4,I)+T*AM(5,I))))
      ARG=ARG+CPI*(TT-T)/W(I)
      GASP=ARG*1.987*4184./W(I)
      RETURN
C     ******************************************************************
      ENTRY COEF
      KOUNT=KOUNT+1
      IF (KOUNT.EQ.2) GO TO 40
      W(I)=TT
      GASP=W(I)
      RETURN
   40 HFU=TT
      AM(6,I)=HFU/1.987
      AL(6,I)=HFU/1.987
      GASP=AL(6,I)
      RETURN
      END
```

```
SUBROUTINE AUXRAD      73/74    OPT=0 TRACE                 FTN 4.6+439       09/24/78  14.08.46       PAGE    1

      SUBROUTINE AUXRAD                                                  AUR        2
      COMMON F(3500),QU(500),QT(500),QV(500),                            CONFB      2
     *  RHO(500),VISC(500),SU(100),SP(100),BMMBOF(500),                 CONFB      3
     1  AXP(100),AXM(100),AYP(100),AYM(100),AZP(100),                   CONFB      4
     2  AZM(100),CZ(100),CY(10),CZU(100),CYU(10),                       CONFB      5
     3  CZP(100),CYP(10),DIVG(100),MTP1,MTP2                            CONFB      6
      DIMENSION U(500),V(500),W(500),PP(500),P(500),TEMP(500)            CONFB      7
      DIMENSION GAM(500)                                                 CONFB      8
      EQUIVALENCE (F(1),U(1)),(F(501),V(1)),(F(1001),W(1))               CONFB      9
      EQUIVALENCE (F(1501),PP(1)),(F(2001),P(1)),(F(2501),TEMP(1))       CONFB     10
      EQUIVALENCE (F(3001),GAM(1))                                       CONFB     11
      COMMON/CTL/R(30),RM(30),RMV(30),YSR(30),YSVR(30),IPLAX             COMMON     2
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),        COMMON     3
     1  YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),     COMMON     4
     2  FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME                         COMMON     5
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NI,NJ,NK,NINJ,NINJNK,NV,  COMMON     6
     1  NNV,NGOTO,K,ISTR,JSTR,KSTR,NVN(20),KM(30),JM(30),ISTEP,         COMMON     7
     2  ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISVP,JSVP,RELAX(16),NP,   COMMON     8
     3  NRMD,NGAM,IWLI(30,5),IWLO(30,5),JWLO(40,5),JWLI(40,5),IWEI,     COMMON     9
     4  IWEG,NNI,JWII,JWIO,JWOI,JWOO,IDW,KKIN(30,30),IKIN(40,30)        COMMON    10
      COMMON/INDEX/IPAR,LPREF,ISTUN,INCONP,ITRAD,NVRX,NVRY,NVRZ,IPLANE   COMMON    11
     1  ,PLANE1,LVX,LVD,LVFOOX,LVFU,LVCO,LVM,LVRX,LVRY,LVRZ,NVF(13),    COMMON    12
     2  IJUMP,IRES,TITLE2(20),IPAX,JMAX,KMAX,NVCO,FUMCO,NVH2O,NVCO2,     COMMON    13
     3  NVN2                                                            COMMON    14
      COMMON/THERM/NVH,NVFU,NVOX,NVFUOX,NVTE,MODEM,IDK,FSTOIC,NFU,CP,    COMMON    15
     1  GASCON,RMOCON,UNICON,PRESS,NVFAV,TCYLW,TINLW,TLIP,ACOEF(4),     COMMON    16
     2  T4,DFAC,WFU,WCO2,WCO,WOX,WH2O,WN2,NYY,CKK,RATIO1,RATIO2,        COMMON    17
     3  RATIO3,RATIO4,HCO,TAN,ITWALL                                    COMMON    18
      COMMON/CTDMA/KEND,ICTDMA(13)                                       COMMON    19
      COMMON/MIS/ANU,DEN,SMAX,SSUM,LASTEP,HTCEXT,CFR,EMISW,EMISIN,       COMGEN     2
     1  EMISR,IOUT,RTCD,EMI,RADIN,RADSUM,FMA,FK,SOFK,                   COMGEN     3
     2  FKFU,FOFU,TFUEL,WFMZ,FLD(40),TEMTR(40),H(40),FUEL(40),FUOX(40) , COMGEN     4
     3  UIN(40),TIN(40),FUELS(40),SEXIT,IGAM1(10),IGAM2(10)             COMGEN     5
      COMMON/TURB/MVK,MVD,C1,C2,CD,AK,OMIDXJ(3,3),AKFAC,ALFAC,           COMGEN     6
     1  MODEL,PR(13),PREF(13),PJAY(13),E                                COMGEN     7
      COMMON/RAD/NVE,SIGMA,AESOR,SCATR                                   COMGEN     8
      COMMON/REACT/ARCON1,PREXP1,CR1,ARCON2,PREXP2,CR2,MODER             COMGEN     9
      COMMON/DROPL/EVAP(192),NTP4,NFMZ,XD(3),YD(3),ZD(3),ALFA(3),        COMGEN    10
     1  BETA(3),DELTA(3),THETA1(3),THETA2(3),WSL(3),WFF(3),SMD(3),      COMGEN    11
     2  VFUEL(3),RFUEL(3),EVSU(64),NEVAP                                COMGEN    12
      COMMON/INJEC/FLOWIN,IUINJ(20),JUINJ(20),UINJ(20),WUINJ(20),        COMGEN    13
     1  AUINJ(20),TUINJ(20),IVINJ(20),JVINJ(20),KVINJ(20),VINJ(20),     COMGEN    14
     2  EVINJ(20),DVINJ(20),AVINJ(20),TVINJ(20),NUINJ,NVINJ,JSW1,JSW2,  COMGEN    15
     3  USW,VSW,AFSW,FSW,TSW,WSW,SWMD,BMOSW                             COMGEN    16
C  ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** **                AUR        6
      ENTRY GAMRAD                                                       AUR        7
      IF (NV.EQ.LVRY) GO TO 3100                                         AUR        8
      DO 3000 K=1,MP1                                                    AUR        9
      DO 3000 J=1,MP1                                                    AUR       10
      KJM=KM(K)+JM(J)                                                    AUR       11
      IS=IWLI(J,4)                                                       AUR       12
      IE=IWLO(J,4)                                                       AUR       13
      DO 3000 I=IS,IE                                                    AUR       14
      LP=KJM+I                                                           AUR       15
      GAM(LP)=1./(ABSOR+SCATR)                                           AUR       16
 3000 CONTINUE                                                           AUR       17
      GO TO 3300                                                         AUR       18
 3100 DO 3200 K=1,MP1                                                    AUR       19
      DO 3200 J=1,MP1                                                    AUR       20
      KJM=KM(K)+JM(J)                                                    AUR       21
      IS=IWLI(J,4)                                                       AUR       22
      IE=IWLO(J,4)                                                       AUR       23
      DO 3200 I=IS,IE                                                    AUR       24
      LP=KJM+I                                                           AUR       25
      GAM(LP)=1./(ABSOR+SCATR+1./(R(J)+1.E-30))                          AUR       26
 3200 CONTINUE                                                           AUR       27
 3300 RETURN                                                             AUR       28
C  ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** *             AUR       29
      ENTRY SORAD                                                        AUR       30
      IF (NV.EQ.LVRZ) GO TO 300                                          AUR       31
      DO 101 J=2,M                                                       AUR       32
      IS=IWLI(J,NGOTO)                                                   AUR       33
      IE=IWLO(J,NGOTO)                                                   AUR       34
      DO 101 I=IS,IE                                                     AUR       35
      LIJ=JM(J)+I                                                        AUR       36
      LP=LIJ+KM(K)                                                       AUR       37
      LPRI=LP+NVR(NVRX)                                                  AUR       38
```

```
SUBROUTINE AJIRAD      73/74    OPT=0 TRACE                    FTN 4.6+439        08/24/78  14.08.46        PAGE     2

          LPRY=LP+NVM(NVRY)                                                        AUR      39
          LPRZ=LP+NVM(NVRZ)                                                        AUR      40
          LPTE=LP+NVM(NVTE)                                                        AUR      41
          FLPTE=F(LPTE)                                                            AUR      42
          FLPE=SIGMA*FLPTE**4                                                      AUR      43
          SU(LIJ)=ABSOR*FLPE+SCATR*(F(LPRX)+F(LPRY)+F(LPRZ))/3.                    AUR      44
          SP(LIJ)=-(ABSOR+SCATR)                                                   AUR      45
      101 CONTINUE                                                                 AUR      46
          RETURN                                                                   AUR      47
      300 CONTINUE                                                                 AUR      48
          DO 391 K=2,N                                                             AUR      49
          KJM=KM(K)+JM(JPLANE)                                                     AUR      50
          IS=IWLI(JPLANE,NGOTO)                                                    AUR      51
          IE=IWLO(JPLANE,NGOTO)                                                    AUR      52
          DO 301 I=IS,IE                                                           AUR      53
          LIK=JM(K)+I                                                              AUR      54
          LP=KJM+I                                                                 AUR      55
          LPRX=LP+NVM(NVRX)                                                        AUR      56
          LPRY=LP+NVM(NVRY)                                                        AUR      57
          LPRZ=LP+NVM(NVRZ)                                                        AUR      58
          LPTE=LP+NVM(NVTE)                                                        AUR      59
          FLPTE=F(LPTE)                                                            AUR      60
          FLPE=SIGMA*FLPTE**4                                                      AUR      61
          SU(LIK)=ABSOR*FLPE+SCATR*(F(LPRX)+F(LPRY)+F(LPRZ))/3.                    AUR      62
          SP(LIK)=-(ABSOR+SCATR)                                                   AUR      63
      301 CONTINUE                                                                 AUR      64
          RETURN                                                                   AUR      65
          END                                                                      AUR      66

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

    48       I                CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
    58       I                CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
    88       I                CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
```

```
      SUBROUTINE SPRAY                                                     SP        2
C ****************.****** SUBROUTINE SPRAY *****************************   SP        3
C     SUBROUTINE FOR AIRTRIP CODE WHICH CALCULATES THE TRAJECTORY          SP        4
C     AND EVAPORATION RATES FOR A FUEL NOZZLE SPRAY.  WRITTEN NOV. 1976    SP        5
C *********************************************************************** SP        6
      COMMON F(3500),DU(500),DV(500),DW(500),                              COMFS     2
     1 RHO(500),VISC(500),SU(100),SP(100),ORHOO(500),                      COMFS     3
     1 AZP(100),IIM(100),AYP(100),AYM(100),AZP(100),                       COMFS     4
     2 AZM(100),CZ(100),CY(10),CZU(100),CYU(10),                           COMFS     5
     3 CZP(100),CYP(10),DIVC(100),KIP1,KIP2                                COMFS     6
      DIMENSION U(500),V(500),W(500),PP(500),P(500),TEMP(500)              COMFS     7
      DIMENSION GAM(500)                                                   COMFS     8
      EQUIVALENCE (F(1),U(1)),(F(501),V(1)),(F(1001),W(1))                 COMFS     9
      EQUIVALENCE (F(1501),PP(1)),(F(2001),P(1)),(F(2501),TEMP(1))         COMFS    10
      EQUIVALENCE (F(3001),GAM(1))                                         COMFS    11
      COMMON/CYL/R(30),RM(30),RMV(30),YSR(30),YSVR(30),IPLAX               COMMON    2
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),          COMMON    3
     1 YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),         COMMON    4
     2 FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME                             COMMON    5
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NT,NJ,NK,NIMJ,NIMJNK,NV,    COMMON    6
     1 NNV,NGOTO,K,ISTE,JSTE,KSTE,NVP(20),KR(30),JM(30),ISTEP,             COMMON    7
     2 ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISWP,JSWP,RELAX(10),NP,      COMMON    8
     3 NRHO,NGAM,IWLI(30,5),IWLO(30,5),JWLO(40,5),JWLI(40,5),IWEI,         COMMON    9
     4 IWEO,NPI,JWII,JWIO,JWOI,JWOO,IOW,JKIN(30,30),IKIN(40,30)            COMMON   10
      COMMON/INDEX/IPAR,LPREF,ISTUN,INCOMP,ITRAD,NVRX,NVRY,NVRZ,JPLANE     COMMON   11
     1 ,PLANMI,LUK,LVD,LVFUOX,LVFU,LVCO,LVH,LVRX,LVRY,LVRZ,NVF(13),        COMMON   12
     2 IJUMP,IRES,TITLE2(20),IMAX,JMAX,KMAX,NVCO,FUNCO,NVH2O,NVCO2,        COMMON   13
     3 NVN2                                                                COMMON   14
      COMMON/THERM/NVH,NVFU,NVOX,NVFUOX,NVTE,MODEN,IOK,FSTOIC,HFU,CP,      COMMON   15
     1 GASCON,RHOCON,UMICON,PRESS,NVFAV,TCYLW,TINLW,TLIP,ACDEF(4),         COMMON   16
     2 T4,DFAC,WFU,WCO2,WCO,WOX,WH2O,WN2,HIT,CXX,RATIO1,RATIO2,            COMMON   17
     3 RATIO3,RATIO4,HCO,TAR,ITWALL                                        COMMON   18
      COMMON/CTOMA/REND,ICTOM(13)                                          COMMON   19
      COMMON/MIS/AMU,DEN,SMAX,SSUM,LASTEP,MTCEXT,CFR,EMISW,EMISIN,         CONGEN    2
     1 EMISR,TOUT,RTCD,ERI,RADIN,RADSUR,FMA,FV,SOFK,                       CONGEN    3
     2 FKFU,FDFU,TFUEL,WFMZ,FLO(40),TEMTM(40),H(40),FUEL(40),FUOX(40) ,    CONGEN    4
     3 UIN(40),TIN(40),FUELS(40),SEXIT,IGAM1(10),IGAM2(10)                 CONGEN    5
      COMMON/TURB/NVK,NVD,C1,C2,CO,AK,DUIDXJ(3,3),AKFAC,ALFAC,             CONGEN    6
     1 MODEL,PR(13),PREF(13),FJAT(13),E                                    CONGEN    7
      COMMON/RAD/NVE,SIGMA,ABSOR,SCATR                                     CONGEN    8
      COMMON/REACT/ARCON1,PREXP1,CR1,ARCON2,PREXP2,CR2,MODER               CONGEN    9
      COMMON/DROVL/EVAP(192),NTP4,NFNZ,XD(3),YD(3),ZD(3),ALFA(3),          CONGEN   10
     1 BETA(3),DELTA(3),THETA1(3),THETA2(3),NSL(3),WFF(3),SMD(3),          CONGEN   11
     2 VFUEL(3),RFUEL(3),EVSU(64),HEVAP                                    CONGEN   12
      COMMON/INJEC/FLOWIN,IUINJ(20),JUINJ(20),UINJ(20),WUINJ(20),          CONGEN   13
     1 AUINJ(20),TUINJ(20),IVINJ(20),JVINJ(20),KVINJ(20),VINJ(20),         CONGEN   14
     2 EVINJ(20),DVINJ(20),AVINJ(20),TVINJ(20),NUINJ,NVINJ,ISW1,ISW2,      CONGEN   15
     3 USW,VSW,AFSW,FSW,TSW,WSW,SWND,RHOSW                                 CONGEN   16
      DIMENSION AXMK(192),AYMK(192),AZMK(192)                              SP       11
      DIMENSION VECX(30),VECY(30),VECZ(30),DSMD(5),XM(40),YM(30),ZM(30)    SP       12
      DIMENSION PO(4),EE(4),FRACT(7),MW(7),MWCOND(4),ACOND(4),BCOND(4)     SP       13
      DIMENSION EVAPU(1),EVAPV(1),EVAPW(1),RVECX(30),RVECY(30),RVECZ(30)   SP       14
      REAL MW,MWCOND,MWT                                                   SP       15
C +-+-+-+-+-+-+-+-  BEWARE OF EQUIVALENCE STATEMENTS  +-+-+-+-+-+-+-+-+-   SP       16
      EQUIVALENCE (EVAPU(1),AXMK(1)),(EVAPV(1),AYMK(1))                    SP       17
      EQUIVALENCE (EVAPW(1),AZMK(1))                                       SP       18
C +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  SP       19
      DATA DSMD/.6,.9,1.2,1.5,2.1/                                         SP       20
      DATA PO,EE/-114.,41.574,96.534,146.57,41.026,30.857,27.348,23.997/   SP       21
      DATA FRACT,MW/0.,.1,.3,.5,.7,.9,1.,93.26,114.6,126.61,138.16         SP       22
     1         ,150.59,173.21,204.76/                                      SP       23
      DATA ACOND,BCOND,MWCOND/-6.362E-3,-6.356E-3,-6.286E-3,-6.01E-3       SP       24
     1,5.36E-5,4.91E-5,4.66E-5,4.23E-5,50.,100.,150.,300./                 SP       25
      DATA NG,NNG,PI,PI2/5,5.,3.14159,6.28318/                             SP       26
C ********************************************************************** SP       27
C -----------SOME PRELIMINARIES                                            SP       28
      IF (NFNZ.LE.0) RETURN                                                SP       29
      SC3=.9283                                                            SP       30
      PR3=.9283                                                            SP       31
      DLIM=.1                                                              SP       32
      ULIM=.1                                                              SP       33
      TF=2300.                                                             SP       34
      HEVAP=30576.5*(1092.88-1.8*TFUEL)**.39                               SP       35
      MFUEL=4.5E+7                                                         SP       36
      RGFD=1000.*(.775+.238-.00072*TFUEL)                                  SP       37
      ZSMALL=(Z(NP1)-Z(1))/FLOAT(NP1)/100.                                 SP       38
      DO 7 K=2,N                                                           SP       39
```

```
      DO 7 J=2,M
      DO 7 I=2,L
      LPC=I-1+(J-2)*(NI-2)+(K-2)*(NI-2)*(NJ-2)
      EVAPU(LPC)=0.
      EVAPV(LPC)=0.
      EVAPW(LPC)=0.
    7 EVAP(LPC)=0.
      XM(1)=X(1)
      DO 115 I=2,L
  115 XM(I)=XM(I-1)+XS(I)
      XM(LP1)=XM(L)
      YM(1)=Y(1)
      DO 17 J=2,M
   17 YM(J)=YM(J-1)+YS(J)
      YM(MP1)=YM(M)
      ZM(1)=Z(1)
      DO 19 K=2,N
   19 ZM(K)=ZM(K-1)+ZS(K)
      ZM(NP1)=ZM(N)
C ***********************************************************************
C ----------LOOP OVER FUEL NOZZLES
      DO 2000 NN=1,NFNZ
      BEE=0.
      NSL2=NSL(NN)
      RNSL=NSL2
      WFI=WFF(NN)/RNSL
C ----------CALCULATE UNIT VECTORS OF SPRAY LINES
      SINA=SIN(ALFA(NN)/2.)
      SINB=SIN(BETA(NN))
      SIND=SIN(DELTA(NN))
      COSA=COS(ALFA(NN)/2.)
      COSB=COS(BETA(NN))
      COSD=COS(DELTA(NN))
      DTHETA=THETA2(NN)-THETA1(NN)
      IF (DTHETA.LT.0.0) DTHETA=DTHETA+PT2
      DANG=DTHETA/(RNSL-1.)
      IF (DTHETA.GT.0.98*PT2) DANG=DTHETA/RNSL
      THETA=THETA1(NN)
      DO 10 IL=1,NSL2
      SINT=SIN(THETA)
      COST=COS(THETA)
      THETA=THETA+DANG
      IF (THETA.GT.PT2) THETA=THETA-PT2
      VECX(IL)=-SINA*SINT*COSB-COSA*SINB
      VECY(IL)=SINA*COST*COSD+SINA*SINT*SINB*SIND-COSA*COSB*SIND
      VECZ(IL)=SINA*COST*SIND-SINA*SINT*SINB*COSD+COSA*COSB*COSD
      RVECX(IL)=-SINT*COSB
      RVECY(IL)=COST*COSD+SINT*SINB*SIND
      RVECZ(IL)=COST*SIND-SINT*SINB*COSD
   10 CONTINUE
C***********************************************************************
C------START CALCULATIONS FOR EVAPORATION RATES-------------------------
      DO 1000 IL=1,NSL2
      DO 1000 IG=1,NG
      UF=VECX(IL)*VFUEL(NN)
      VF=VECY(IL)*VFUEL(NN)
      WF=VECZ(IL)*VFUEL(NN)
      DIA=SMD(NN)*1.E-6*DSMD(IG)
      TFU=TFUEL
      ITYPE=1
      DIAO=DIA
      CONZ=0.
      IGPNT=-10
      IF (ISTEP.NE.IGPNT) GO TO 7746
      WRITE (6,7747)
 7747 FORMAT (/10X,'UF',10X,'VF',10X,'WF',9X,'UST',9X,'VST',9X,'WST',
     1 7X,'FEVAP',10X,'XF',10X,'YF',10X,'ZF')
 7746 CONTINUE
      FEVAP=0.
      DO 11 I=1,LPI
      ILOC=I
      IF (XO(NN).GT.XM(I)) GO TO 11
      GO TO 12
   11 CONTINUE
   12 DO 13 J=1,MP1
      JLOC=J
      IF (YO(NN).GT.YM(J)) GO TO 13
```

```
      GO TO 14
   13 CONTINUE
   14 DO 15 K=1,NP1
      KLOC=K
      IF (ZO(NN).GT.ZM(K)) GO TO 15
      GO TO 16
   15 CONTINUE
   16 XF=XO(NN)+RFUEL(NN)*RVECX(IL)
      YF=YO(NN)+RFUEL(NN)*RVECY(IL)
      ZF=ZO(NN)+RFUEL(NN)*RVECZ(IL)/(R(I)+PLAXMI*YF)
C-----LOCATION OF THE DROPLET------------
  110 CONTINUE
      IOLD=ILOC
      JOLD=JLOC
      KOLD=KLOC
C ----X DROPLET LOCATION
      IF (XF.GE.XM(ILOC-1).AND.XF.LT.XM(ILOC)) GO TO 27
      DO 22 I=1,LP1
      ILOC=I
      IF (XF.GT.XM(I)) GO TO 22
      GO TO 27
   22 CONTINUE
C ----Y DROPLET LOCATION
   27 IF (YF.GE.YM(JLOC-1).AND.YF.LT.YM(JLOC)) GO TO 23
      DO 24 J=1,MP1
      JLOC=J
      IF (YF.GT.YM(J)) GO TO 24
      GO TO 23
   24 CONTINUE
C ----Z DROPLET LOCATION
   23 IF (ZF.GE.ZM(KLOC-1).AND.ZF.LT.ZM(KLOC)) GO TO 63
      DO 26 K=1,NP1
      KLOC=K
      IF (ZF.GT.ZM(K)) GO TO 26
      GO TO 48
   26 CONTINUE
   48 IF (KLOC.GT.1) GO TO 28
      KLOC=N
      ZF=Z(NP1)-ZSMALL
   28 IF (KLOC.LT.NP1) GO TO 63
      KLOC=2
      ZF=Z(1)+ZSMALL
C ----DROPLET NEAR A WALL
   63 INDX=0
      IF (ILOC.GE.IWLI(JLOC,4)) GO TO 43
      ILOC=IOLD
      XF=AMAX1(XF,XM(ILOC-1)+DIA/2.)
      XF=AMIN1(XF,XM(ILOC)-DIA/2.)
      INDX=1
   43 IF (ILOC.LE.IWLO(JLOC,4)) GO TO 47
      IF (JLOC.GT.JWOI.AND.JLOC.LT.JWOO) GO TO 1000
      ILOC=IOLD
      XF=AMAX1(XF,XM(ILOC-1)+DIA/2.)
      XF=AMIN1(XF,XM(ILOC)-DIA/2.)
      INDX=2
   47 IF (JLOC.GT.JWLI(ILOC,4)) GO TO 44
      IF (IOW.EQ.0) GO TO 50
      JLOC=JOLD
      YF=AMAX1(YF,YM(JLOC-1)+DIA/2.)
      YF=AMIN1(YF,YM(JLOC)-DIA/2.)
      INDX=3
   44 IF (JLOC.LT.JWLO(ILOC,4)) GO TO 41
      JLOC=JOLD
      YF=AMAX1(YF,YM(JLOC-1)+DIA/2.)
      YF=AMIN1(YF,YM(JLOC)-DIA/2.)
      INDX=4
C ----CHECK FOR SLOTS
   41 IF (NUINJ.LE.0) GO TO 45
      DO 149 II=1,NUINJ
      IJ=IJINJ(II)-1
      JU=JUINJ(II)
      IF (ILOC.EQ.IU.AND.JLOC.EQ.JU) GO TO 50
  149 CONTINUE
   45 CONTINUE
      GO TO 63
C ---------DROPLET HAS HIT SOLID BOUNDARY
   50 ILOC=IOLD
```

```
      JLOC=JOLD
      KLOC=KOLD
      DEVAP=1.-FEVAP
      UF=0.
      VF=0.
      WF=0.
      FX=0.
      FY=0.
      FZ=0.
      GO TO 249
C --------NO BOUNDRIES HAVE BEEN HIT
   60 CONTINUE
      LP=KN(KLOC)+JN(JLOC)+ILOC
      LXP=LP+1
      LYP=LP+NI
      LZP=LP+NINJ
      LPTE=LP+NVN(NVTE)
      LPFUOX=LP+NVN(NVFUOX)
C ------- CAREFUL HERE
      LPFU=LP+NVN(NVFU+3)
      LPCO=LP+NVN(NVCO+1)
C -----FREESTREAM PROPERTIES
      ROST=RHO(LP)
      TST=F(LPTE)
      UST=FXP(ILOC)*U(LP)+FXM(ILOC)*U(LXP)
      VST=FYP(JLOC)*V(LP)+FYM(JLOC)*V(LYP)
      WST=FZP(KLOC)*W(LP)+FZM(KLOC)*W(LZP)
      IB=INLI(JLOC,4)
      IF (XF.GE.X(IB)) GO TO 51
      IF (JMIN(JLOC,KLOC).EQ.1) GO TO 51
      FAC=((XF-XM(IB-1))/(X(IB)-XM(IB-1)))**.14286
      UST=0.
      VST=VST*FAC
      WST=WST*FAC
      IF (INDX.NE.1) GO TO 51
      UF=UST
      VF=VST
      WF=WST
   51 IB=INLO(JLOC,4)
      IF (XF.LE.X(IB)) GO TO 56
      IF (JLOC.GT.JWOI.AND.JLOC.LT.JWOO) GO TO 56
      FAC=((XM(IB)-XF)/(XM(IB)-X(IB)))**.14286
      UST=0.
      VST=VST*FAC
      WST=WST*FAC
      IF (INDX.NE.2) GO TO 56
      UF=UST
      VF=VST
      WF=WST
   56 JB=JWLI(ILOC,4)
      IF (YF.GE.Y(JB+1)) GO TO 53
      IF (IKIN(ILOC,KLOC).EQ.1.OR.IKIN(ILOC,KLOC).EQ.3) GO TO 53
      FAC=((YF-YM(JB))/(Y(JB+1)-YM(JB)))**.14286
      UST=UST*FAC
      VST=0.
      WST=WST*FAC
      IF (INDX.NE.3) GO TO 53
      UF=UST
      VF=VST
      WF=WST
   53 JB=JWLO(ILOC,4)
      IF (YF.LE.Y(JB-1)) GO TO 54
      IF (IKIN(ILOC,KLOC).EQ.2.OR.IKIN(ILOC,JLOC).EQ.3) GO TO 54
      FAC=((YM(JB-1)-YF)/(YM(JB-1)-Y(JB-1)))**.14286
      UST=UST*FAC
      VST=0.
      WST=WST*FAC
      IF (INDX.NE.4) GO TO 54
      UF=UST
      VF=VST
      WF=WST
   54 CONTINUE
      FLPOX=RATIO1*F(LPFU)+RATIO3*F(LPCO)+RATIO2-(RATIO2+RATIO1)*
     2F(LPFUOX)
      FLPOX=AMAX1(FLPOX,0.)
      IF (ISTEP.NE.IGRNT) GO TO 7744
      WRITE (6,7745) UF,VF,WF,UST,VST,WST,FEVAP,XF,YF,ZF
```

```
 7745 FORMAT (10E12.4)
 7744 CONTINUE
C -----BOILING TEMPERATURE OF FUEL-----------------------------------
      POT=PO(4)
      ET=EE(4)
      IF(FEVAP.GE.0.5) GO TO 200
      POT=TAB(FEVAP,FRACT,PG,4)
      ET=TAB(FEVAP,FRACT,EE,4)
  200 TB=ET*ALOG(PRESS)+POT
      TI=(TB+TF)/2.
      TFU=AMIN1(TFU,TB)
C------DENSITY OF LIQUID FUEL AT TB
      ROF=1.076/(1.+(1.076/.775-1.)*(1.-.67*FEVAP))
      ROF=1000.*(ROF+.209-.00072*TFU)
C------MOLECULAR WEIGHT OF FUEL VAPORS
      MWT=TAB(FEVAP,FRACT,MW,7)
      AT=TAB(MWT,MWCOND,ACOND,4)
  300 BT=TAB(MWT,MWCOND,BCOND,4)
C------THERMAL CONDUCTIVITY AND SPECIFIC HEAT OF FUEL VAPORS
      COND1=1.729*(AT+BT*TI)
      CP1=CPDR(TI,1)
  400 COND1=0.4*COND1+0.6*.064*SQRT(TI/1111.)
C -----RELATIVE VEL, REYNOLDS NO.,DRAG COEF AND FORCE COMPONENTS
      VR=SQRT((UF-UST)**2+(VF-VST)**2+(WF-WST)**2)
      VISCO=4.464E-5*SQRT(TST/1111.)
      REI=ROST*VR*DIA/VISCO
      SREI=SQRT(REI)
      CDS=2.0
      IF (REI.GT.22.16.AND.REI.LE.80.) CDS=27./REI**.84
      IF (REI.GT.80..AND.REI.LT.10000.) CDS=.271*REI**.217
      CD1=AMAX1(CDS/2.,CDS/(1.+BEE))
      CONS=CD1*3.14159/4.*DIA**2/2.*ROST
      DM=PI*DIA**3*ROF/6.
      FX=CONS*ABS(UF-UST)*(UST-UF)
      FY=CONS*ABS(VF-VST)*(VST-VF)+PLAXM1*DM*WF*WF/R(JLOC)
      FZ=CONS*ABS(WF-WST)*(WST-WF)-PLAXM1*DM*VF*WF/R(JLOC)
      VFU=SQRT(UF**2+VF**2+WF**2)
      FAC=AMAX1(1.0,25./(VR*VR+1.E-20))
      DTI1=ULIM*VFU*DM*FAC/(ABS(FX)+1.E-30)
      DTI2=ULIM*VFU*DM*FAC/(ABS(FY)+1.E-30)
      DTI3=ULIM*VFU*DM*FAC/(ABS(FZ)+1.E-30)
      DTI4=DLIM/((COM2+1.E-30)
      DTI5=XS(ILOC)/(ABS(UF)+1.E-20)
      DTI6=YS(JLOC)/(ABS(VF)+1.E-20)
      DTI7=R(JLOC)*ZS(KLOC)/(ABS(WF)+1.E-20)
      DTI=AMIN1(DTI1,DTI2,DTI3,DTI4,DTI5,DTI6,DTI7)
      CONS=DM/DTI
C------VELOCITY AND LOCATION OF THE DROPLET
      UFO=UF
      VFO=VF
      WFO=WF
      UF=UF+FX/CONS
      VF=VF+FY/CONS
      WF=WF+FZ/CONS
      IF (UFO.GT.UST) UF=AMAX1(UF,UST-.001)
      IF (UFO.LT.UST) UF=AMIN1(UF,UST+.001)
      IF (VFO.GT.VST) VF=AMAX1(VF,VST-.001)
      IF (VFO.LT.VST) VF=AMIN1(VF,VST+.001)
      IF (WFO.GT.WST) WF=AMAX1(WF,WST-.001)
      IF (WFO.LT.WST) WF=AMIN1(WF,WST+.001)
      DX=.5*(UF+UFO)*DTI
      DY=.5*(VF+VFO)*DTI
      DZ=.5*(WF+WFO)*DTI
      XF=XF+DX
      YF=YF+DY
      ZF=ZF+DZ/R(JLOC)
      IF (TFU.GE.TB) ITYPE=2
      GO TO (185,199), ITYPE
C------------ HEATING DROPLET ------------------------------------------
C -----HEAT TRANSFER
  185 HT=COND1*(2.+.6*PR3*SREI)/DIA
      AS=PI*DIA*DIA
      QDOT=AS*HT*(TST-TFU)
      CPLF=540.5+4.1372*TFU
      DTF=DTI*QDOT/DM/CPLF
      TFU=TFU+DTF
      GO TO 110
```

```
C -----------   BOILING DROPLET  --------------------------------------
C------MASS TRANSFER NUMBER
  199 IF IF(LPFUEL)-FSTOIC) 210,205,201
  201 BEE=AMAX1(CP1*(TST-TB)/HEVAP,0.)
      GO TO 215
  205 BEE=FLPOX/RATIO1
      GO TO 215
  210 BEE=(FL*HR*WFUEL/RATIO1+AMAX1(CP1*(TST-TB),0.))/HEVAP
  215 RATE=8./RDF*COND1/CP1*ALOG(1.+BEE)*(1.+0.276*SREI*SC3)
C------FRACTION EVAPORATED
      COM2=1.5/RDF0/DIA0**3*RDF*DIA*RATE
      DEVAP=COM2*DTI
  240 FEVAP=FEVAP+DEVAP
      IF (FEVAP.LT.1.0) GO TO 250
      DEVAP=DEVAP-FEVAP+1.
      FEVAP=1.
C -----NEW DROPLET DIAMETER
  250 ARG=DIA*DIA-RATE*DTI
      IF (ARG.GT.0.0) GO TO 262
      DEVAP=DEVAP+1.-FEVAP
      FEVAP=1.0
      GO TO 252
  262 DIA=SQRT(ARG)
C -------------  FUEL EVAPORATION FLOW RATE   --------------------------
  252 AMT=DEVAP*WFI/RNG
      LPC=ILOC-1+(JLOC-2)*(NI-2)+(KLOC-2)*(NI-2)*(NJ-2)
      EVAP(LPC)=EVAP(LPC)+AMT
      EVAPU(LPC)=EVAPU(LPC)+AMT*UF
      EVAPV(LPC)=EVAPV(LPC)+AMT*VF
      EVAPW(LPC)=EVAPW(LPC)+AMT*WF
  900 IF (FEVAP.LT.0.99) GO TO 110
 1000 CONTINUE
 2000 CONTINUE
C ************************************************************************
C -------  STORE MOMENTUM DATA ON TAPE4
      REWIND NTP4
      DO 1100 K=2,N
      DO 1110 J=2,M
      KJC=(K-2)*(NI-2)*(NJ-2)+(J-2)*(NI-2)
      DO 1110 I=3,L
      LIJ=(J-2)*(NI-2)+(I-1)
      LPC=KJC+(I-1)
      LXMC=LPC-1
      EVSU(LIJ)=FXM(I-1)*EVAPU(LXMC)+FXP(I)*EVAPU(LPC)
      IF (I.EQ.3) EVSU(LIJ)=EVSU(LIJ)+FXP(2)*EVAPU(LXMC)
      IF (I.EQ.L) EVSU(LIJ)=EVSU(LIJ)+FXM(L)*EVAPU(LPC)
 1110 CONTINUE
      WRITE (NTP4) EVSU
 1100 CONTINUE
      DO 1200 K=2,N
      DO 1210 J=3,M
      KJC=(K-2)*(NI-2)*(NJ-2)+(J-2)*(NI-2)
      DO 1210 I=2,L
      LIJ=(J-2)*(NI-2)+(I-1)
      LPC=KJC+(I-1)
      LYMC=LPC-(NI-2)
      EVSU(LIJ)=FYM(J-1)*EVAPV(LYMC)+FYP(J)*EVAPV(LPC)
      IF (J.EQ.3) EVSU(LIJ)=EVSU(LIJ)+FYP(2)*EVAPV(LYMC)
      IF (J.EQ.M) EVSU(LIJ)=EVSU(LIJ)+FYM(M)*EVAPV(LPC)
 1210 CONTINUE
      WRITE (NTP4) EVSU
 1200 CONTINUE
      DO 1300 K=3,NP1
      DO 1310 J=2,M
      KJC=(K-2)*(NI-2)*(NJ-2)+(J-2)*(NI-2)
      DO 1310 I=2,L
      LIJ=(J-2)*(NI-2)+(I-1)
      LPC=KJC+(I-1)
      LZMC=LPC-(NI-2)*(NJ-2)
      EVSU(LIJ)=FZM(K-1)*EVAPW(LZMC)
      IF (K.EQ.NP1) GO TO 1309
      EVSU(LIJ)=EVSU(LIJ)+FZP(K)*EVAPW(LPC)
      GO TO 1310
 1309 EVSU(LIJ)=EVSU(LIJ)+FZP(2)*EVAPW(LIJ)
 1310 CONTINUE
      WRITE (NTP4) EVSU
 1300 CONTINUE
```

```
      RETURN                                          SP      425
      END                                             SP      426
```

CARD NR.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
77	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
94	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
157	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
186	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
376	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
422	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
435	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
449	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.

```
FUNCTION TAB          73/74    OPT=0 TRACE                   FTN 4.6+439          08/24/76  14.08.46        PAGE    1

                  FUNCTION TAB (X,XX,YY,NTAB)                                      SP        427
                  DIMENSION XX(1),YY(1)                                            SP        428
                  IF (NTAB.GT.0) GO TO 5                                           SP        429
                  TAB=0.0                                                          SP        430
                  RETURN                                                           SP        431
                5 F=1                                                              SP        432
                  IF (XX(1).GT.XX(2)) F=-F                                         SP        433
                  DO 10 J=1,NTAB                                                   SP        434
                  I=J                                                              SP        435
                  IF (F*(XX(I)-X)) 10,40,20                                        SP        436
               10 CONTINUE                                                         SP        437
               20 IF (I.NE.1) GO TO 30                                             SP        438
                  I=2                                                              SP        439
               30 J=I-1                                                            SP        440
                  DEL=XX(I)-XX(J)                                                  SP        441
                  IF (DEL.EQ.0.0) GO TO 50                                         SP        442
                  TAB=(YY(I)*(X-XX(J))-YY(J)*(X-XX(I)))/DEL                        SP        443
                  RETURN                                                           SP        444
               40 TAB=YY(I)                                                        SP        445
                  RETURN                                                           SP        446
               50 WRITE (6,60) X,I,J                                               SP        447
               60 FORMAT (* *** ERROR IN SUBROUTINE TAB ***,E15.4,2I5)             SP        448
                  STOP                                                             SP        449
                  END                                                              SP        450

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

     7      I        XX        ARRAY REFERENCE OUTSIDE DIMENSION BOUNDS.
```

```
      SUBROUTINE STRIDE
      COMMON F(3500),DU(500),DV(500),DW(500),
     1  RHO(500),VISC(500),SU(100),SP(100),DRHODP(500),
     2  AXP(100),AXM(100),AYP(100),AYM(100),AZP(100),
     3  AZM(100),CZ(100),CY(10),CZG(100),CYU(10),
     4  CZP(100),CYP(10),DIFF(100),NTPL,NTPZ
      DIMENSION U(500),V(500),W(500),PP(500),P(500),TEMP(500)
      DIMENSION GAM(500)
      EQUIVALENCE (F(1),U(1)),(F(501),V(1)),(F(1001),W(1))
      EQUIVALENCE (F(1501),PP(1)),(F(2001),P(1)),(F(2501),TEMP(1))
      EQUIVALENCE (F(3001),GAM(1))
      COMMON/CYL/R(30),RM(30),RMV(30),YSR(30),YSVR(30),IPLAX
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),
     1  YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),
     2  FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NI,NJ,NK,NIJ,NIJNK,NV,
     1  NNJ,NCCTD,K,ISTR,JSTR,KSTR,NVP(20),KM(30),JM(30),ISTEP,
     2  ISOLVE(13),IPRINT(22),TITLE(16,22),IXY,ISMP,JSMP,RELAX(16),MP,
     3  NRHO,NGEP,INLI(30,5),INLO(30,5),JNLO(40,5),JNLI(40,5),INEI,
     4  INE2,NNI,JNI1,JNI2,JNO1,JNO2,IDW,JKIN(30,30),IKIN(40,30)
      COMMON/INDEX/IPAR,LPREF,ISTUM,INCORP,ITRAD,NVRX,NVRY,NVRZ,IPLANE
     1  ,PLANEI,LVX,LVD,LVFUDX,LVFU,LVCD,LVM,LVRX,LVRY,LVRZ,NVF(13),
     2  IJUMP,IRES,TITLE2(20),IPRX,JMAX,KMAX,NVCO,FUNCO,NUM20,NVCO2,
     3  NVN2
      COMMON/THERM/NUM,NVFU,NVOX,NVFUOX,NVTE,MODEM,IOX,FSTOIC,HFU,CP,
     1  GASCON,RHOCON,UNICON,PRESS,NVFAV,TCYLM,TIMLM,TLIP,ACOEF(4),
     2  T0,OFAC,AFU,ACO2,ACO,WTI,WH2O,WN2,HVY,CXX,RATIO1,RATIO2,
     3  RATIO3,RATIO4,NCG,TAW,ITCALL
      COMMON/CTOMA/KEND,ICTOMA(13)
      ENTRY STRIDC
      IXY=1
      ISMP=1
      JSMP=1
      TIME=0.
      L=LP1-1
      M=MP1-1
      N=NP1-1
      LCV=L-1
      MCV=M-1
      NCV=N-1
      NM1=N-1
      NIJ=NI*NJ
      NIJNK=NIJ*NK
      NVM(1)=0
      DO 1 NV=2,NGAM
    1 NVP(NV)=NVM(NV-1)+NIJNK
      KM(1)=0
      DO 2 K=2,NP1
    2 KM(K)=KM(K-1)+NIJ
      JM(1)=0
      MAX=MAX0(MP1,NP1)
      DO 3 J=2,MAX
    3 JM(J)=JM(J-1)+NI
      RETURN
C  ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** *
      ENTRY STRIDI
      DO 101 I=2,LP1
  101 XDIF(I)=X(I)-X(I-1)
      DO 111 I=2,L
  111 XS(I)=0.5*(X(I+1)-X(I-1))
      XS(2)=XS(2)+0.5*XDIF(2)
      XS(L)=XS(L)+0.5*XDIF(LP1)
      DO 121 I=3,L
      XSU(I)=XDIF(I)
      FXP(I)=XDIF(I)/(2.*XS(I))
  121 FXM(I)=1.-FXP(I)
      XSU(3)=XSU(3)+XDIF(2)
      XSU(L)=XSU(L)+XDIF(LP1)
      FXP(2)=FXP(3)
      FXM(2)=1.-FXP(2)
      FXP(L)=FXP(L-1)
      FXM(L)=1.-FXP(L)
      DO 102 J=2,MP1
  102 YDIF(J)= Y(J)- Y(J-1)
      DO 112 J=2,M
  112 YS(J)= 0.5*(Y(J+1)-Y(J-1))
      YS(2)=YS(2)+0.5*YDIF(2)
```

```
      YS(N)=YS(N)+0.5*YDIF(NP1)
      RM(2)=R(1)
      DO 122 J=3,N
      RM(J)=.5*(R(J)+R(J-1))
      RMV(J+1)=R(J)
      YSV(J)=YDIF(J)
      FYP(J)=YDIF(J)/(2.*YS(J))
  122 FYM(J)=1.-FYP(J)
      RM(NP1)=R(NP1)
      RMV(3)=R(1)
      RMV(NP1)=R(NP1)
      YSV(3)=YSV(3)+YDIF(2)
      YSV(N)=YSV(N)+YDIF(NP1)
      FYP(2)=FYP(3)
      FYM(2)=1.-FYP(2)
      FYP(N)=FYP(N-1)
      FYM(N)=1.-FYP(N)
      DO 132 J=2,N
  132 YSR(J)=.5*(RM(J+1)+RM(J))*YS(J)
      DO 142 J=3,N
  142 YSVR(J)=.5*(RMV(J+1)+RMV(J))*YSV(J)
      DO 103 K=2,NP1
  103 ZDIF(K)=Z(K)-Z(K-1)
      DO 113 K=2,N
  113 ZS(K)=0.5*(Z(K+1)-Z(K-1))
      ZS(2)=ZS(2)+0.5*ZDIF(2)
      ZS(N) = ZS(N)+0.5*ZDIF(NP1)
      ZS(NP1)=ZS(2)
      DO 123 K=3,N
      ZSW(K)=ZDIF(K)
      FZP(K)=ZDIF(K)/(2.*ZS(K))
  123 FZM(K)=1.-FZP(K)
      ZSW(NP1)=ZDIF(2)+ZDIF(NP1)
      FZP(NP1)=ZDIF(2)/ZS(NP1)
      FZM(NP1)=1.-FZP(NP1)
      FZP(2)=ZDIF(2)/ZS(2)
      FZM(2)=1.-FZP(2)
      DO 290 I=1,LP1
      IP=MIN0(I+1,LP1)
      IL=MAX0(I-1,1)
      JWLI(I,1)=MAX0(JWLI(I,4),JWLI(IL,4))
      JWLI(I,2)=JWLI(I,4)+1
      JWLI(I,3)=JWLI(I,4)
      JWLI(I,5)=MIN0(JWLI(IP,4),JWLI(I,4),JWLI(IL,4))
      JWLO(I,1)=MIN0(JWLO(I,4),JWLO(IL,4))
      JWLO(I,2)=JWLO(I,4)
      JWLO(I,3)=JWLO(I,4)
      JWLO(I,5)=MAX0(JWLO(IP,4),JWLO(I,4),JWLO(IL,4))
  290 CONTINUE
      DO 292 J=1,MP1
      JP=MIN0(J+1,MP1)
      JL=MAX0(J-1,1)
      IWLI(J,1)=IWLI(J,4)+1
      IWLI(J,2)=MAX0(IWLI(J,4),IWLI(JL,4))
      IWLI(J,3)=IWLI(J,4)
      IWLI(J,5)=MIN0(IWLI(JP,4),IWLI(J,4),IWLI(JL,4))-1
      IWLO(J,1)=IWLO(J,4)
      IWLO(J,2)=MIN0(IWLO(J,4),IWLO(JL,4))
      IWLO(J,3)=IWLO(J,4)
      IWLO(J,5)=MAX0(IWLO(JP,4),IWLO(J,4),IWLO(JL,4))+1
  292 CONTINUE
      RETURN
C  ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** *
      ENTRY STRID2
C -+-+-+-+-+-+-+-+-+-+-+-   U-VELOCITY   +-+-+-+-+-+-+-+-+-+-+-+-+-
      DO 360 LP=1,MINJMK
  360 SU(LP)=0.0
      IF(ISOLVE(1)) 303,302,302
  303 IF(MOD(ISTEP,ISOLVE(1))) 302,304,302
  304 CONTINUE
      ISTR=3
      JSTR=2
      KSTR=2
      NV=1
      NGOTO=1
      CALL GAMMA
      DO 30 J=2,N
```

```
      IS=IWLI(J,NGOTO)                                                 ST   130
      IE=IWLO(J,NGOTO)                                                 ST   131
      TZFAC=R(J)/(R(M)+DFAC*(R(J)-R(M)))                               ST   132
      DO 30 I=IS,IE                                                    ST   133
      LP=JM(J)+I                                                       ST   134
      LZP=LP+NINJ                                                      ST   135
      LPI1=LP-1                                                        ST   136
      LZPI=LZP-1                                                       ST   137
      AREA=XSU(I)*YS(J)                                                ST   138
      ALZ=RHO(LP)*W(LZP)*AREA                                          ST   139
      ALZI=RHO(LPI1)*W(LZPI)*AREA                                      ST   140
      ALZ=.5*(ALZ+ALZI)                                                ST   141
      ALZ=ALZ/2.                                                       ST   142
      TZ=.5*(GAM(LP)+GAM(LPI1))*AREA*TZFAC/(ZSW(NPI)*R(J))             ST   143
      TZ=AMAX1(TZ,ABS(ALZ))                                            ST   144
      CZU(LP)=2.*ALZ                                                   ST   145
   30 CZ(LP)=TZ+ALZ                                                    ST   146
      DO 301 K=2,M                                                     ST   147
      CALL SOURCE                                                      ST   148
      CALL SOMAS                                                       ST   149
      DO 31 I=3,L                                                      ST   150
      JS=JWLI(I,NGOTO)+1                                               ST   151
      AREA=XSU(I)*ZS(K)*RM(JS)                                         ST   152
      LP=NM(K)+JM(JS)+I                                                ST   153
      LYM=LP-NI                                                        ST   154
      LXMI=LYM-1                                                       ST   155
      LXM=LP-1                                                         ST   156
      IF (JWLI(I,4).EQ.JS-1) GO TO 150                                 ST   157
      ALY=.5*(RHO(LP)+RHO(LYM))*V(LP)*AREA                             ST   158
      TY=.5*(GAM(LP)+GAM(LYM))*AREA/YDIF(JS)                           ST   159
      GO TO 152                                                        ST   160
  150 ALY=RHO(LYM)*V(LP)*AREA                                          ST   161
      DIST=.5*YDIF(JS)                                                 ST   162
      IF (JS.EQ.2) DIST=YDIF(2)                                        ST   163
      TY=GAM(LYM)*AREA/DIST                                            ST   164
  152 IF (JWLI(I-1,4).EQ.JS-1) GO TO 154                               ST   165
      ALYI=.5*(RHO(LXM)+RHO(LXMI))*V(LXM)*AREA                         ST   166
      TYI=.5*(GAM(LXM)+GAM(LXMI))*AREA/YDIF(JS)                        ST   167
      GO TO 156                                                        ST   168
  154 ALYI=RHO(LXMI)*V(LXM)*AREA                                       ST   169
      DIST=.5*YDIF(JS)                                                 ST   170
      IF (JS.EQ.2) DIST=YDIF(JS)                                       ST   171
      TYI=GAM(LXMI)*AREA/DIST                                          ST   172
  156 ALY=.5*(ALY+ALYI)                                                ST   173
      TY=.5*(TY+TYI)                                                   ST   174
      TY=AMAX1(TY,-ALY)                                                ST   175
      CYU(I)=ALY                                                       ST   176
   31 CY(I)=TY+ALY                                                     ST   177
      DO 32 J=2,N                                                      ST   178
      KJM=NM(K)+JM(J)                                                  ST   179
      AREA=YSR(J)*ZS(K)                                                ST   180
      IS=IWLI(J,NGOTO)                                                 ST   181
      IE=IWLO(J,NGOTO)                                                 ST   182
      I=IS-1                                                           ST   183
      LXP=KJM+IS                                                       ST   184
      LP=LXP-1                                                         ST   185
      LXM=LP-1                                                         ST   186
  200 ALXM=RHO(LXM)*U(LP)*AREA                                         ST   187
      ALXO=0.                                                          ST   188
      TX=GAM(LXM)*AREA/XS(I)                                           ST   189
      CXU=ALXM                                                         ST   190
  202 TX=AMAX1(TX,ALXM)                                                ST   191
      TX=AMAX1(TX,-ALXP)                                               ST   192
      CX=TX+ALXM                                                       ST   193
      TZFAC=R(J)/(R(M)+DFAC*(R(J)-R(M)))                               ST   194
      DO 32 I=IS,IE                                                    ST   195
      NAX=IWLO(I,NGOTO)-1                                              ST   196
      LIJ=JM(J)+I                                                      ST   197
      LP=KJM+I                                                         ST   198
      LXP=LP+1                                                         ST   199
      LYP=LP+NI                                                        ST   200
      LZP=LP+NINJ                                                      ST   201
      LPI1=LP-1                                                        ST   202
      LYPI=LYP-1                                                       ST   203
      LZPI=LZP-1                                                       ST   204
      AXM(LIJ)=CX                                                      ST   205
      AYM(LIJ)=CY(I)                                                   ST   206
```

```
      AZM(LIJ)=CZ(LIJ)
      AREA=YSR(J)*ZS(K)
      IF (I.EQ.IE) GO TO 33
      ALX=RHO(LP)*AREA*(FXP(I)*U(LXP)+FXM(I)*U(LP))
      ALXP=FXP(I)*ALX
      ALXM=FXM(I)*ALX
      TX=GAM(LP)*AREA/XS(I)
      CXUP=ALX
      GO TO 34
   33 ALXP=RHO(LXP)*U(LXP)*AREA
      ALXM=0.
      TX=GAM(LXP)*AREA/XS(L)
      CXUP=ALXP
   34 TX=AMAX1(TX,ALXP)
      TX=AMAX1(TX,-ALXM)
      AXP(LIJ)=TX-ALXP
      CX=TX+ALXM
      DIVG(LIJ)=DIVG(LIJ)+CXUP-CXU
      CXU=CXUP
      AREA=ZS(K)*XSU(I)*RM(J+1)
      IF (J.EQ.MAX) GO TO 35
      ALY=.25*(RHO(LP)+RHO(LYP))*V(LYP)*AREA
      ALY1=.25*(RHO(LP1)+RHO(LYP1))*V(LYP1)*AREA
      ALY=.5*(ALY+ALY1)
      TY=.25*(GAM(LP)+GAM(LYP)+GAM(LP1)+GAM(LYP1))*AREA/YDIF(J+2)
      TY=AMAX1(TY,ABS(ALY))
      CYUP=2.*ALY
      GO TO 36
   35 IF (JWLD(I,4).EQ.MAX+1) GO TO 157
      ALY=.5*(RHO(LP)+RHO(LYP))*V(LYP)*AREA
      TY=.5*(GAM(LP)+GAM(LYP))*AREA/YDIF(MAX+1)
      GO TO 158
  157 ALY=RHO(LYP)*V(LYP)*AREA
      DIST=.5*YDIF(MAX+1)
      IF (MAX.EQ.M) DIST=YDIF(MP1)
      TY=GAM(LYP)*AREA/DIST
  158 IF (JWLD(I-1,4).EQ.MAX+1) GO TO 159
      ALY1=.5*(RHO(LP1)+RHO(LYP1))*V(LYP1)*AREA
      TY=.5*(GAM(LP1)+GAM(LYP1))*AREA/YDIF(MAX+1)
      GO TO 160
  159 ALY1=RHO(LYP1)*V(LYP1)*AREA
      DIST=.5*YDIF(MAX+1)
      IF (MAX.EQ.M) DIST=YDIF(MP1)
      TY1=GAM(LYP1)*AREA/DIST
  160 ALY=.5*(ALY+ALY1)
      TY=.5*(TY+TY1)
      TY=AMAX1(TY,ALY)
      CYUP=ALY
   36 AYP(LIJ)=TY-ALY
      CY(I)=TY+ALY
      DIVG(LIJ)=DIVG(LIJ)+CYUP-CYU(I)
      CYU(I)=CYUP
      AREA=XSU(I)*YS(J)
      IF(K.EQ.N) GO TO 37
      ALZ=.25*(RHO(LP)+RHO(LZP))*W(LZP)*AREA
      ALZ1=.25*(RHO(LP1)+RHO(LZP1))*W(LZP1)*AREA
      ALZ=.5*(ALZ+ALZ1)
      GAMLP=.25*(GAM(LP)+GAM(LZP)+GAM(LP1)+GAM(LZP1))
      TZ=GAMLP*AREA*TZFAC/(ZDIF(K+1)*R(J))
      TZ=AMAX1(TZ,ABS(ALZ))
      CZUP=2.*ALZ
      GO TO 38
   37 ALZ=RHO(LZP)*W(LZP)*AREA
      ALZ1=RHO(LZP1)*W(LZP1)*AREA
      ALZ=.5*(ALZ+ALZ1)
      ALZ=ALZ/2.
      TZ=.5*(GAM(LZP)+GAM(LZP1))*AREA*TZFAC/(ZS(N+1)*R(J))
      TZ=AMAX1(TZ,ABS(ALZ))
      CZUP=2.*ALZ
   38 AZP(LIJ)=TZ-ALZ
      CZ(LIJ)=TZ+ALZ
      DIVG(LIJ)=DIVG(LIJ)+CZUP-CZU(LIJ)
      CZU(LIJ)=CZUP
      VOL=XSU(I)*YSR(J)*ZS(K)
      IF (I.EQ.IWL(J,NGJTO).AND.I.GT.3) VOL=VOL*(1.+.5*XSU(I-1)/XSU(I))
      IF (I.EQ.IWLO(J,NGJTO).AND.I.LT.L) VOL=VOL*(1.+.5*XSU(I+1)/XSU(I))
      LP=LP-1
```

```
   39   RDT=0.
   392  DIVG(LIJ)=AMAX1(RDT,DIVG(LIJ))
        DU(LP)=VOL/XDIF(I)
        SU(LIJ)=SU(LIJ)*VOL+DU(LP)*(P(LIM)-P(LP))+DIVG(LIJ)*U(LP)
        SP(LIJ)=SP(LIJ)*VOL-DIVG(LIJ)
     32 CONTINUE
        CALL SORDD
        CALL SOLVE1
    301 CONTINUE
        CALL SOLVE2
        CALL FROG
    302 CONTINUE
C *-*-*-*-*-*-*-*-*-*-*-*-*-   V-VELOCITY    *-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
        DO 460 LP=1,MINJMK
    460 DV(LP)=0.0
        IF(ISOLVE(2)) 403,402,403
   403  IF(MOD(ISTEP,ISOLVE(2))) 402,404,402
   404  CONTINUE
        ISTR=2
        JSTR=3
        KSTR=2
        NU=2
        NGOTO=2
        CALL GAMMA
        DO 40 J=3,M
        IS=IWLI(J,NGOTO)
        IE=IWLO(J,NGOTO)
        TZFAC=RM(J)/(RM(M)+DFAC*(RM(J)-RM(M)))
        DO 40 I=IS,IE
        LP=JM(J)+I
        LZP=LP+NIJ
        LPI1=LP-NI
        LZPI1=LZP-NI
        AREA=XS(I)*YSV(J)
        ALZ=RHO(LP)*W(LZP)*AREA
        ALZ1=RHO(LPI1)*W(LZPI1)*AREA
        ALZ=.5*(ALZ+ALZ1)
        ALZ=ALZ/2.
        TZ=.5*(GAM(LP)+GAM(LPI1))*AREA*TZFAC/(ZSW(NP1)*RM(J))
        TZ=AMAX1(TZ,ABS(ALZ))
        CZU(LP)=2.*ALZ
     40 CZ(LP)=TZ+ALZ
        DO 401 K=2,N
        CALL SOURCE
        CALL SOMAS
        DO 41 I=2,L
        J=JWLI(I,NGOTO)
        AREA=ZS(K)*XS(I)*RMV(J+1)
        LP=KM(K)+JM(J)+I
        LYP=LP+NI
        LYM=LP-NI
    206 ALYM=RHO(LYM)*V(LP)*AREA
        ALYP=0.
        TY=GAM(LYM)*AREA/YS(J)
        CYU(I)=ALYM
    209 TY=AMAX1(TY,ALYP)
        TY=AMAX1(TY,-ALYM)
     41 CY(I)=TY+ALYM
        DO 42 J=3,M
        KJM=KM(K)+JM(J)
        IS=IWLI(J,NGOTO)
        IE=IWLO(J,NGOTO)
        LXP=KJM+IS
        LP=LXP-1
        LPI1=LP-NI
        LXPI=LXP-NI
        AREA=YSV(J)*ZS(K)
        IF (IWLI(J,4).EQ.IS) GO TO 162
        ALX=.5*(RHO(LP)+RHO(LXP))*U(LXP)*AREA
        TX=.5*(GAM(LP)+GAM(LXP))*AREA/XDIF(IS)
        GO TO 163
    162 ALX=RHO(LP)*U(LXP)*AREA
        DIST=.5*XDIF(IS)
        IF (IS.EQ.2) DIST=XDIF(2)
        TX=GAM(LP)*AREA/DIST
    163 IF (IWLI(J-1,4).EQ.IS) GO TO 164
        ALX1=.5*(RHO(LPI1)+RHO(LXP1))*U(LXP1)*AREA
```

```
      TX1=.5*(GAM(LPI1)+GAM(LXP1))*AREA/XDIF(IS)
      GO TO 165
  164 ALX1=RHO(LPI1)*U(LXP1)*AREA
      DIST=.5*XDIF(IS)
      IF (IS.EQ.2) DIST=XDIF(2)
      TX1=GAM(LPI1)*AREA/DIST
  165 ALX=.5*(ALX+ALX1)
      TX=.5*(TX+TX1)
      TX=AMAX1(TX,-ALX)
      CXU=ALX
      CX=TX+ALX
      TZFAC=RM(J)/(RM(M)+DFAC*(RM(J)-RM(M)))
      DO 42 I=IS,IE
      MAX=JWLO(I,NGOTO)-I
      LIJ=JM(J)+I
      LP=KJM+I
      LXP=LP+1
      LYP=LP+NI
      LZP=LP+NINJ
      LPI1=LP-NI
      LXPI=LXP-NI
      LZPI=LZP-NI
      AXM(LIJ)=CX
      AYM(LIJ)=CY(I)
      AZM(LIJ)=CZ(LIJ)
      AREA=YSUR(J)*ZS(K)
      IF (I.EQ.IE) GO TO 43
      ALX=.25*(RHO(LP)+RHO(LXP))*U(LXP)*AREA
      ALX1=.25*(RHO(LPI1)+RHO(LXPI))*U(LXPI)*AREA
      ALX=.5*(ALX+ALX1)
      TX=.25*(GAM(LP)+GAM(LXP)+GAM(LPI1)+GAM(LXP1))*AREA/XDIF(I+1)
      TX=AMAX1(TX,ABS(ALX))
      CXUP=2.*ALX
      GO TO 44
   43 IF (IWLO(J,4).EQ.IE) GO TO 167
      ALX=.5*(RHO(LP)+RHO(LXP))*U(LXP)*AREA
      TX=.5*(GAM(LP)+GAM(LXP))*AREA/XDIF(I+1)
      GO TO 168
  167 ALX=RHO(LXP)*U(LXP)*AREA
      DIST=.5*XDIF(I+1)
      IF (I.EQ.L) DIST=XDIF(LP1)
      TX=GAM(LXP)*AREA/DIST
  168 IF (IWLO(J-1,4).EQ.IE) GO TO 169
      ALX1=.5*(RHO(LPI1)+RHO(LXP1))*U(LXP1)*AREA
      TX1=.5*(GAM(LPI1)+GAM(LXP1))*AREA/XDIF(I+1)
      GO TO 170
  169 ALX1=RHO(LXP1)*U(LXP1)*AREA
      DIST=.5*XDIF(I+1)
      IF (I.EQ.L) DIST=XDIF(LP1)
      TX1=GAM(LXP1)*AREA/DIST
  170 ALX=.5*(ALX+ALX1)
      TX=.5*(TX+TX1)
      TX=AMAX1(TX,ALX)
      CXUP=ALX
   44 AXP(LIJ)=TX-ALX
      CX=TX+ALX
      DIVG(LIJ)=DIVG(LIJ)+CXUP-CXU
      CXU=CXUP
      AREA=ZS(K)*XS(I)*RMV(J+1)
      IF (J.EQ.JWLO(I,NGOTO)-1) GO TO 45
      ALY=RHO(LP)*AREA*(FYP(J)*V(LYP)+FYM(J)*V(LP))
      ALYP=FYP(J)*ALY
      ALYM=FYM(J)*ALY
      TY=GAM(LP)*AREA/YS(J)
      CYUP=ALY
      GO TO 46
45    ALYP=RHO(LYP)*V(LYP)*AREA
      ALYM=0.
      TY=GAM(LYP)*AREA/YS(J)
      CYUP=ALYP
46    TY=AMAX1(TY,ALYP)
      TY=AMAX1(TY,-ALYM)
      AYP(LIJ)=TY-ALYP
      CY(I)=TY+ALYM
      DIVG(LIJ)=DIVG(LIJ)+CYUP-CYU(I)
      CYU(I)=CYUP
      AREA=XS(I)*YSV(J)
```

```
      IF(K.EQ.N) GO TO 47
      ALZ=.25*(RHO(LP)+RHO(LZP))*W(LZP)*AREA
      ALZ1=.25*(RHO(LP11)+RHO(LZP1))*W(LZP1)*AREA
      ALZ=.5*(ALZ+ALZ1)
      GAMLP=.25*(GAM(LP)+GAM(LZP)+GAM(LP11)+GAM(LZP1))
      TZ=GAMLP*AREA*TZFAC/(ZDIF(K+1)*RM(J))
      TZ=AMAX1(TZ,ABS(ALZ))
      CZUP=2.*ALZ
      GO TO 48
   47 ALZ=RHO(LZP)*W(LZP)*AREA
      ALZ1=RHO(LZP1)*W(LZP1)*AREA
      ALZ=.5*(ALZ+ALZ1)
      ALZ=ALZ/2.
      TZ=GAM(LZP)*AREA*TZFAC/(ZS(NP1)*RM(J))
      TZ=AMAX1(TZ,ABS(ALZ))
      CZUP=2.*ALZ
   48 AZP(LIJ)=TZ-ALZ
      CZ(LIJ)=TZ+ALZ
      DIVG(LIJ)=DIVG(LIJ)+CZUP-CZU(LIJ)
      CZU(LIJ)=CZUP
      VOL=XS(I)*YSVR(J)*ZS(K)
      IF (J.EQ.JWLI(I,NGOTO).AND.J.GT.3) VOL=VOL*(1.+.5*YSVR(J-1)/
     1    YSVR(J))
      IF (J.EQ.JWLO(I,NGOTO).AND.J.LT.M) VOL=VOL*(1.+.5*YSVR(J+1)/
     1    YSVR(J))
      LYM=LP-NI
   40 PDT=0.
  402 DIVG(LIJ)=AMAX1(PDT,DIVG(LIJ))
      DV(LP)=VOL/YDIF(J)
      SU(LIJ)=SU(LIJ)*VOL+DV(LP)*(P(LYM)-P(LP))+DIVG(LIJ)*V(LP)
      SP(LIJ)=SP(LIJ)*VOL-DIVG(LIJ)
      SU(LIJ)=SU(LIJ)+PLAX*1*0.5*(RHO(LP)+RHO(LP-NI))*(0.25*(W(LP)+W(LP+
     1NINJ)+W(LP+NINJ-NI)+W(LP-NI)))**2*VOL/RM(J)
   42 CONTINUE
      CALL SCMOD
      CALL SOLVE1
  401 CONTINUE
      CALL SOLVE2
      CALL EMOD
  402 CONTINUE
C +-+-+-+-+-+-+-+-+-+-+-+-+-+-   W-VELOCITY   +-+-+-+-+-+-+-+-+-+-+-+-+-+-
      DO 505 LP=1,NINJNK
  505 DW(LP)=0.0
      IF(ISOLVE(3)) 503,502,503
  503 IF(MOD(ISTEP,ISOLVE(3))) 502,504,502
  504 CONTINUE
      ISTP=2
      JSTP=2
      KSTP=3
      NV=3
      NGOTO=3
      CALL GAMMA
      DO 55 J=2,M
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      TZFAC=1.0
      DO 55 I=IS,IE
      LIJ=JM(J)+I
      LP=KM(2)+LIJ
      LZP=LP+NINJ
      AREA=XS(I)*YS(J)
      ALZ=RHO(LP)*AREA*(FZP(2)*W(LZP)+FZM(2)*W(LP))
      ALZP=FZP(2)*ALZ
      ALZM=FZM(2)*ALZ
      TZ=GAM(LP)*AREA*TZFAC/(ZS(2)*R(J))
      CZU(LIJ)=ALZ
      TZ=AMAX1(TZ,ALZP)
      TZ=AMAX1(TZ,-ALZM)
   55 CZ(LIJ)=TZ+ALZM
      DO 501 K=3,NPI
      CALL SOURCE
      CALL SORAS
      DO 51 I=2,L
      J=JWLI(I,NGOTO)+I
      LP=KM(K)+JM(J-1)+I
      LYP=LP+NI
      LP11=LP-NINJ
```

```
      LYP1=LYP-NINJ
      AREA=ZSW(K)*XS(I)*RM(J)
      ALY=RHO(LP)*V(LYP)*AREA
      ALY1=RHO(LP11)*V(LYP1)*AREA
      ALY=.5*(ALY+ALY1)
      DIST=.5*YDIF(J)
      IF (J.EQ.2) DIST=YDIF(2)
      TY=.5*(GAM(LP)+GAM(LP11))*AREA/DIST
      TY=AMAX1(TY,-ALY)
      CYU(I)=ALY
   51 CY(I)=TY+ALY
      DO 52 J=2,M
      KJM=KM(K)+JM(J)
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      LXP=KJM+IS
      LP=LXP-1
      LP11=LP-NINJ
      LXP1=LXP-NINJ
      AREA=YSR(J)*ZSW(K)
      ALX=RHO(LP)*U(LXP)*AREA
      ALX1=RHO(LP11)*U(LXP1)*AREA
      ALX=.5*(ALX+ALX1)
      DIST=.5*XDIF(IS)
      IF (IS.EQ.2) DIST=XDIF(2)
      TX=.5*(GAM(LP)+GAM(LP11))*AREA/DIST
      TX=AMAX1(TX,-ALX)
      CXU=ALX
      CX=TX+ALX
      TZFAC=1.0
      DO 52 I=IS,IE
      MAX=JWLO(I,NGOTO)-1
      LIJ=JM(J)+I
      LP=KJM+I
      LXP=LP+1
      LYP=LP+NI
      LZP=LP+NINJ
      LP11=LP-NINJ
      LXP1=LXP-NINJ
      LYP1=LYP-NINJ
      AXM(LIJ)=CX
      AYM(LIJ)=CY(I)
      AZM(LIJ)=CZ(LIJ)
      AREA=YSR(J)*ZSW(K)
      IF (I.EQ.IE) GO TO 53
      ALX=.25*(RHO(LP)+RHO(LXP))*U(LXP)*AREA
      ALX1=.25*(RHO(LP11)+RHO(LXP1))*U(LXP1)*AREA
      ALX=.5*(ALX+ALX1)
      TX=.25*(GAM(LP)+GAM(LXP)+GAM(LP11)+GAM(LXP1))*AREA/XDIF(I+1)
      TX=AMAX1(TX,ABS(ALX))
      CXUP=2.*ALX
      GO TO 54
   53 ALX=RHO(LXP)*U(LXP)*AREA
      ALX1=RHO(LXP1)*U(LXP1)*AREA
      ALX=.5*(ALX+ALX1)
      DIST=.5*XDIF(I+1)
      IF (I.EQ.L) DIST=XDIF(LP1)
      TX=.5*(GAM(LXP)+GAM(LXP1))*AREA/DIST
      TX=AMAX1(TX,ALX)
      CXUP=ALX
   54 AXP(LIJ)=TX-ALX
      CX=TX+ALX
      DIVG(LIJ)=DIVG(LIJ)+CXUP-CXU
      CXU=CXUP
      AREA=ZSW(K)*XS(I)*RM(J+1)
      IF (J.EQ.MAX) GO TO 55
      ALY=.25*(RHO(LP)+RHO(LYP))*V(LYP)*AREA
      ALY1=.25*(RHO(LP11)+RHO(LYP1))*V(LYP1)*AREA
      ALY=.5*(ALY+ALY1)
      TY=.25*(GAM(LP)+GAM(LYP)+GAM(LP11)+GAM(LYP1))*AREA/YDIF(J+1)
      TY=AMAX1(TY,ABS(ALY))
      CYUP=2.*ALY
      GO TO 56
   55 ALY=RHO(LYP)*V(LYP)*AREA
      ALY1=RHO(LYP1)*V(LYP1)*AREA
      ALY=.5*(ALY+ALY1)
      DIST=.5*YDIF(J+1)
```

```
      IF (J.EQ.M) DIST=YDIF(MP1)
      TY=.5*(GAM(LYP)+GAM(LYP1))*AREA/DIST
      TY=AMAX1(TY,ALY)
      CYUP=ALY
   56 AYP(LIJ)=TY-ALY
      CY(I)=TY+ALY
      DIVG(LIJ)=DIVG(LIJ)+CYUP-CYU(I)
      CYU(I)=CYUP
      AREA=XS(I)*YS(J)
      DENSTY=RHO(LP)
      IF(K.EQ.NP1) DENSTY=RHO(LIJ+MINJ)
      IF (K.EQ.NP1) WLZP=W(LIJ+2*MINJ)
      IF(K.LT.NP1) WLZP=W(LZP)
      ALZ=DENSTY*AREA*(FZP(K)*WLZP+FZM(K)*W(LP))
      ALZP=FZP(K)*ALZ
      ALZM=FZM(K)*ALZ
      TZ=GAM(LP)*AREA*TZFAC/(ZS(K)*R(J))
      CZUP=ALZ
      TZ=AMAX1(TZ,ALZP)
      TZ=AMAX1(TZ,-ALZM)
      AZP(LIJ)=TZ-ALZP
      CZ(LIJ)=TZ+ALZM
      DIVG(LIJ)=DIVG(LIJ)+CZUP-CZU(LIJ)
      CZU(LIJ)=CZUP
      VOL=XS(I)*YSR(J)*ZSW(K)
      LZM=LP-MINJ
59    RDT=0.
592   DIVG(LIJ)=AMAX1(RDT,DIVG(LIJ))
      DW(LP)=VOL/ZDIF(K)/R(J)
      IF (K.EQ.NP1) DW(LP)=DW(LP)*ZDIF(K)/ZSW(K)
      SU(LIJ)=SU(LIJ)*VOL+DW(LP)*(P(LZM)-P(LP))+DIVG(LIJ)*W(LP)
      SP(LIJ)=SP(LIJ)*VOL-DIVG(LIJ)
      SP(LIJ)=SP(LIJ)-0.5*(RHO(LP)+RHO(LP-MINJ))*0.25*(V(LP)+V(LP-MINJ)+
     1V(LP+NI)+V(LP-MINJ+NI))/R(J)*VOL*PLAXM1
   52 CONTINUE
      CALL SORDD
      CALL SOLVE1
  501 CONTINUE
      CALL SOLVE2
502   CONTINUE
      CALL VELMOD
C +-+-+-+-+-+-+-+-+-+-+-   PRESSURE PERTABATION EQUATION  +-+-+-+-+-+-+-+-+-+-
      NGOTO=4
      IF(ISOLVE(4)) 603,602,603
603   IF(MOD(ISTEP,ISOLVE(4))) 602,604,602
604   CONTINUE
      DO 605 LP=1,NINJNK
  605 PP(LP)=0.0
      ISTR=2
      JSTR=2
      KSTR=2
      NY=4
 6000 CONTINUE
      DO 62 J=2,M
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      DO 60 I=IS,IE
      LP=JM(J)+I
      LZP=LP+MINJ
      RHOA=RHO(LP)*XS(I)*YS(J)
      CZU(LP)=RHOA*W(LZP)
   55 CZ(LP)=RHOA*DW(LZP)
      DO 601 K=2,N
      DO 61 I=2,L
      J=JWLI(I,NGOTO)+1
      LP=KM(K)+JM(J-1)+I
      LVP=LP+NI
      RHOA=RHO(LP)*ZS(K)*XS(I)*RM(J)
      CYU(I)=RHOA*V(LVP)
   61 CY(I)=RHOA*DV(LVP)
      DO 62 J=2,M
      KJM=KM(K)+JM(J)
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      LP=KJM+IS-1
      LUP=LP+1
      RHOA=RHO(LP)*YSR(J)*ZS(K)
```

```
      CXU=RHOA*U(LXP)
      CX=RHOA*DU(LXP)
      DO 62 I=IS,IE
      MAX=JWLO(I,NGOTO)-I
      LIJ=JR(J)+I
      LP=KJM+I
      LXP=LP+1
      LYP=LP+NI
      LZP=LP+NINJ
      AXM(LIJ)=CX
      AYM(LIJ)=CY(I)
      AZM(LIJ)=CZ(LIJ)
      IF (I.EQ.IE) GO TO 63
      RHOA=0.5*(RHO(LP)+RHO(LXP))*YS(J)*ZS(K)
      GO TO 64
63    RHOA=RHO(LXP)*YSR(J)*ZS(K)
   64 CX=RHOA*DU(LXP)
      CXUP=RHOA*U(LXP)
      SU(LIJ)=CXU-CXUP
      CXU=CXUP
      AXP(LIJ)=CX
      IF (J.EQ.MAX) GO TO 65
      RHOA=0.5*(RHO(LP)+RHO(LYP))*ZS(K)*XS(I)*RM(J+1)
      GO TO 66
   65 RHOA=RHO(LYP)*ZS(K)*XS(I)*RM(J+1)
   66 CY(I)=RHOA*DV(LYP)
      CYUP=RHOA*V(LYP)
      SU(LIJ)=SU(LIJ)+CYU(I)-CYUP
      CYU(I)=CYUP
      AYP(LIJ)=CY(I)
      IF(K.EQ.N) GO TO 67
      RHOA=0.5*(RHO(LP)+RHO(LZP))*XS(I)*YS(J)
      GO TO 68
67    RHOA=RHO(LZP)*XS(I)*YS(J)
   68 CZ(LIJ)=RHOA*DW(LZP)
      CZUP=RHOA*W(LZP)
      SU(LIJ)=SU(LIJ)+CZU(LIJ)-CZUP
      CZU(LIJ)=CZUP
      AZP(LIJ)=CZ(LIJ)
      SP(LIJ)=0.
62    CONTINUE
      CALL SOMOD
      CALL SOLVE1
601     CONTINUE
      CALL SOLVE2
  602 CONTINUE
C COME HERE TO CORRECT VELOCITIES AND PRESSURES
      CALL FROD
      DO 620 K=2,NP1
      DO 620 J=2,MP1
      KJM=KM(K)+JM(J)
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)+1
      DO 620 I=IS,IE
      LP=KJM+I
      LXM=LP-1
      LYM=LP-NI
      LZM=LP-NINJ
      U(LP)=U(LP)+DU(LP)*(PP(LXM)-PP(LP))
      V(LP)=V(LP)+DV(LP)*(PP(LYM)-PP(LP))
      W(LP)=W(LP)+DW(LP)*(PP(LZM)-PP(LP))
620   CONTINUE
      GO TO (621,622),IPAP
  622 PLPREF=P(LPREF)+PP(LPREF)*RELAX(NP)
  621 CONTINUE
      DO 630 K=2,N
      DO 630 J=2,M
      KJM=KM(K)+JM(J)
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      DO 630 I=IS,IE
      LP=KJM+I
      P(LP)=P(LP)+PP(LP)*RELAX(NP)
      GO TO (631,632),IPAP
  632 P(LP)=P(LP)-PLPREF
  631 CONTINUE
633   PP(LP)=0.
```

```
      DO 641 J=1,MP1
      DO 641 I=1,LP1
      LPM=I+JM(J)+KM(MP1)
      LP2=I+JM(J)+KM(2)
      P(LPM)=P(LP2)
  641 CONTINUE
      REWIND NTP2
      WRITE (NTP2) U,V,W,P
C +-+-+-+-+-+-+-+-+-+-+-+-+-+-   F-VARIABLES   +-+-+-+-+-+-+-+-+-+-+-+-+-+
      DO 700 NV=5,NNV
      IF (NV.NE.LVK) GO TO 710
      REWIND NTP1
      READ (NTP1)
C ---- HERE PP IS KE,  P IS DISSIPATION
      READ (NTP1) PP,P
  710 IF (NV.NE.LVFUOX) GO TO 714
C ------- HERE PP IS KE, P IS DISS
      WRITE (NTP2) PP,P
C ------- HERE PP IS PHI, P IS MFU, DU IS MCO
      READ (NTP1) PP,P,DU
  714 IF (NV.NE.LVH) GO TO 720
C ------- HERE DV IS ENTHALPY, DW IS FAV
      READ (NTP1) DV,DW
      DO 716 K=1,MP1
      DO 717 I=1,LP1
      IF (IKIN(I,K).EQ.2.OR.IKIN(I,K).EQ.3) GO TO 712
      LP=KM(K)+JM(JWLI(I,4))+I
      LPH=LP+NVM(NVH)
      F(LPH)=RATIO2*HDR(TEMP(LP),4)+(1.-RATIO2)*HDR(TEMP(LP),12)
  712 IF (IKIN(I,K).EQ.1.OR.IKIN(I,K).EQ.3) GO TO 717
      LP=KM(K)+JM(JWLO(I,4))+I
      LPH=LP+NVM(NVH)
      F(LPH)=RATIO2*HDR(TEMP(LP),4)+(1.-RATIO2)*HDR(TEMP(LP),12)
  717 CONTINUE
      DO 716 J=1,MP1
      IF (JKIN(J,K).EQ.1) GO TO 760
      LP=KM(K)+JM(J)+IWLI(J,4)-1
      LPH=LP+NVM(NVH)
      F(LPH)=RATIO2*HDR(TEMP(LP),4)+(1.-RATIO2)*HDR(TEMP(LP),12)
  760 IF (J.GT.JWCI.AND.J.LT.JWCO) GO TO 716
      LP=KM(K)+JM(J)+IWLO(J,4)+1
      LPH=LP+NVM(NVH)
      F(LPH)=RATIO2*HDR(TEMP(LP),4)+(1.-RATIO2)*HDR(TEMP(LP),12)
  716 CONTINUE
  720 IF (ISOLVE(NV)) 703,702,703
  703 IF (MOD(ISTEP,ISOLVE(NV))) 702,704,702
  704 CONTINUE
      ISTR=2
      JSTR=2
      KSTR=2
      CALL GAMMA
      DO 70 J=2,M
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      TZFAC=R(J)/(R(M)+DFAC*(R(J)-R(M)))
      DO 70 I=IS,IE
      LP=JM(J)+I
      LZP=LP+NIM1
      AREA=XS(I)*YS(J)
      ALZ=RHO(LP)*W(LZP)*AREA
      ALZ=ALZ/2.
      TZ=GAM(LP)*AREA*TZFAC/(ZSW(MP1)*R(J))
      TZ=AMAX1(TZ,ABS(ALZ))
      CZU(LP)=2.*ALZ
   70 CZ(LP)=TZ+ALZ
      DO 703 K=2,N
      CALL SOURCE
      CALL SOMAS
      DO 71 I=2,L
      J=JWLI(I,NGOTO)+1
      LP=KM(K)+JM(J-1)+I
      LYP=LP+NI
      AREA=ZS(K)*XS(I)*RM(J)
      ALY=RHO(LP)*V(LYP)*AREA
      DIST=.5*YDIF(J)
      IF (J.EQ.2) DIST=YDIF(2)
      TY=GAM(LP)*AREA/DIST
```

```
      TY=AMAX1(TY,-ALY)
      CYU(I)=ALY
   71 CY(I)=TY+ALY
      DO 72 J=2,M
      KJM=KM(K)+JM(J)
      IS=IWLI(J,NGOTO)
      IE=IWLO(J,NGOTO)
      LXP=KJM+IS
      LP=LXP-1
      AREA=YSR(J)*ZS(K)
      ALX=RHO(LP)*U(LXP)*AREA
      DIST=.5*XDIF(IS)
      IF (IS.EQ.2) DIST=XDIF(2)
      TX=GAM(LP)*AREA/DIST
      TX=AMAX1(TX,-ALX)
      CXU=ALX
      CX=TX+ALX
      TZFAC=R(J)/(R(M)+DFAC*(R(J)-R(M)))
      DO 72 I=IS,IE
      MAX=JWLO(I,NGOTO)-1
      LIJ=JM(J)+I
      LP=KJM+I
      LXP=LP+1
      LYP=LP+NI
      LZP=LP+NIMJ
      AXM(LIJ)=CX
      AYM(LIJ)=CY(I)
      AZM(LIJ)=CZ(LIJ)
      AREA=YSR(J)*ZS(K)
      IF (I.EQ.IE) GO TO 73
      ALX=.25*(RHO(LP)+RHO(LXP))*U(LXP)*AREA
      TX=.5*(GAM(LP)+GAM(LXP))*AREA/XDIF(I+1)
      TX=AMAX1(TX,ABS(ALX))
      CXUP=2.*ALX
      GO TO 74
   73 ALX=RHO(LXP)*U(LXP)*AREA
      DIST=.5*XDIF(I+1)
      IF (I.EQ.L) DIST=XDIF(LP1)
      TX=GAM(LXP)*AREA/DIST
      TX=AMAX1(TX,ALX)
      CXUP=ALX
   74 AXP(LIJ)=TX-ALX
      CX=TX+ALX
      DIVG(LIJ)=DIVG(LIJ)+CXUP-CXU
      CXU=CXUP
      AREA=ZS(K)*XS(I)*RM(J+1)
      IF (J.EQ.MAX) GO TO 75
      ALY=.25*(RHO(LP)+RHO(LYP))*V(LYP)*AREA
      TY=.5*(GAM(LP)+GAM(LYP))*AREA/YDIF(J+1)
      TY=AMAX1(TY,ABS(ALY))
      CYUP=2.*ALY
      GO TO 76
   75 ALY=RHO(LYP)*V(LYP)*AREA
      DIST=.5*YDIF(J+1)
      IF (J.EQ.M) DIST=YDIF(MP1)
      TY=GAM(LYP)*AREA/DIST
      TY=AMAX1(TY,ALY)
      CYUP=ALY
   76 AYP(LIJ)=TY-ALY
      CY(I)=TY+ALY
      DIVG(LIJ)=DIVG(LIJ)+CYUP-CYU(I)
      CYU(I)=CYUP
      AREA=XS(I)*YS(J)
      IF(K.EQ.N) GO TO 77
      ALZ=.25*(RHO(LP)+RHO(LZP))*W(LZP)*AREA
      TZ=.5*(GAM(LP)+GAM(LZP))*AREA*TZFAC/(ZDIF(K+1)*R(J))
      TZ=AMAX1(TZ,ABS(ALZ))
      CZUP=2.*ALZ
      GO TO 78
   77 ALZ=RHO(LZP)*W(LZP)*AREA
      ALZ=ALZ/2.
      TZ=GAM(LZP)*AREA*TZFAC/(ZSM(NP1)*R(J))
      TZ=AMAX1(TZ,ABS(ALZ))
      CZUP=2.*ALZ
   78 AZP(LIJ)=TZ-ALZ
      CZ(LIJ)=TZ+ALZ
      DIVG(LIJ)=DIVG(LIJ)+CZUP-CZU(LIJ)
```

```
925           CZU(LIJ)=CZUP                                             ST     900
              VOL=XS(I)*YS(J)*ZS(K)                                     ST     901
         79   RST=0.                                                    ST     902
         792  DIVG(LIJ)=AMAX1(ROT,DIVG(LIJ))                            ST     903
              LPF=LP+NVM(NVF(NV))                                       ST     904
930           SU(LIJ)=SU(LIJ)+VOL*DIVG(LIJ)*F(LPF)                      ST     905
              SP(LIJ)=SP(LIJ)+VOL-DIVG(LIJ)                             ST     906
            72 CONTINUE                                                 ST     907
              CALL SORCD                                                ST     908
              CALL SOLVE1                                               ST     909
935        701 CONTINUE                                                 ST     910
              CALL SOLVE2                                               ST     911
              CALL FMOD                                                 ST     912
         702  CONTINUE                                                  ST     913
          700 CONTINUE                                                  ST     914
940      C *-*-*-*-*-*-*-*-*-*-*-*-*-   RADIATION EQUATIONS   *-*-*-*-*-*-*-*-*-*-*-*-*-  ST  915
         C ------ HERE U IS FX,  V IS FY,  W IS FZ                      ST     916
              READ (NTP1) U,V,W                                         ST     917
              IMD=0                                                     ST     918
              DO 730 NV=LVRX,LVRZ                                       ST     919
945           IF (ISOLVE(NV)) 733,730,733                               ST     920
          733 IF (MOD(ISTEP,ISOLVE(NV))) 730,734,730                    ST     921
          734 IF (IMD.EQ.0) CALL CAMRAD                                 ST     922
              IF (IPLAT.EQ.1) IMD=1                                     ST     923
              CALL STRAD                                                ST     924
950           CALL FMOD                                                 ST     925
          730 CONTINUE                                                  ST     926
         C ----  COMPUTE AVG RADIATION FLUX  ------                     ST     927
              DO 740 K=1,NPI                                            ST     928
              DO 740 J=1,MPI                                            ST     929
955           KJM=KM(K)+JM(J)                                           ST     930
              DO 740 I=1,LPI                                            ST     931
              LP=KJM+I                                                  ST     932
              LPRX=LP+NVM(NVRX)                                         ST     933
              LPRY=LP+NVM(NVRY)                                         ST     934
960           LPRZ=LP+NVM(NVRZ)                                         ST     935
              LPFAV=LP+NVM(NVFAV)                                       ST     936
          740 F(LPFAV)=(F(LPRX)+F(LPRY)+F(LPRZ))/3.                     ST     937
         C ------- HERE PP IS PHI, P IS MFU, DU IS MCO                  ST     938
              WRITE (NTP2) PP,P,DU                                      ST     939
965      C ------- HERE DV IS ENTHALPY, DW IS FAV                       ST     940
              WRITE (NTP2) DV,DW                                        ST     941
         C ------ HERE U IS FX,  V IS FY,  W IS FZ                      ST     942
              WRITE (NTP2) U,V,W                                        ST     943
              WRITE (NTP2) TEMP,RHO                                     ST     944
970       799 NTPT=NTP1+NTP2                                            ST     945
              NTP1=NTPT-NTP1                                            ST     946
              NTP2=NTPT-NTP2                                            ST     947
         800  ISTEP=ISTEP+1                                             ST     948
              IXY= 3-IXY                                                ST     949
975           RETURN                                                    ST     950
              END                                                       ST     951
```

CARD NR.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
45	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
68	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
99	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
101	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
126	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
132	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
351	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
535	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
679	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
742	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
756	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
759	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
767	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
780	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
794	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
836	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
944	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
953	I		CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.

```
          SUBROUTINE STRAD                                                STR       2
          COMMON/CDEF/A(40),B(40),EP(30),DP(30),APP(30),BPP(30)           STR       3
          COMMON F(3500),DU(500),DV(500),DW(500),                         COMFB     2
         1 RHO(500),VISC(500),SU(100),SP(100),DRMDDP(500),                COMFB     3
         1 AXP(100),AXM(100),AYP(100),AYM(100),AZP(100),                  COMFB     4
         2 AZM(100),CZ(100),CV(10),CZU(100),CVU(10),                      COMFB     5
         3 CZP(100),CYP(10),DIVG(100),NTPI,NTPZ                           COMFB     6
          DIMENSION U(500),V(500),W(500),PP(500),P(500),TEMP(500)         COMFB     7
          DIMENSION GAM(500)                                              COMFB     8
          EQUIVALENCE (F(1),U(1)),(F(501),V(1)),(F(1001),W(1))            COMFB     9
          EQUIVALENCE (F(1501),PP(1)),(F(2001),P(1)),(F(2501),TEMP(1))    COMFB    10
          EQUIVALENCE (F(3001),GAM(1))                                    COMFB    11
          COMMON/CYL/R(30),RM(30),RMV(30),YSR(30),YSVR(30),IPLAX          COMMON    2
          COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),     COMMON    3
         1 YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),    COMMON    4
         2 FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME                        COMMON    5
          COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NI,NJ,NK,NIMJ,NIMJNK,NV, COMMON  6
         1 NNV,NGOTO,K,ISTR,JSTR,KSTR,NVR(20),KM(30),JM(30),ISTEP,        COMMON    7
         2 ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISWP,JSWP,RELAX(16),NP, COMMON    8
         3 NRHO,NGAM,IWLI(30,5),IWLO(30,5),JWLO(40,5),JWLI(40,5),IWEI,    COMMON    9
         4 IWEO,NMI,JWII,JWIO,JWOI,JWOO,IOW,JKIN(30,30),IKIN(40,30)       COMMON   10
          COMMON/INDEX/IPAK,LPREF,ISTGN,NCOPP,ITRAD,NVRX,NVRY,NVRZ,IPLANE COMMON   11
         1 ,PLAXI,LVK,LVD,LVFUOX,LVFU,LVCO,LVH,LVRX,LVRY,LVRZ,NVF(13),    COMMON   12
         2 IJUMP,IRES,TITLE2(20),IMAX,JMAX,KMAX,NVCO,FUMCO,NVH2O,NVCO2,   COMMON   13
         3 NVN2                                                           COMMON   14
          COMMON/THERM/NVH,NVFU,NVOX,NVFUOX,NVTE,MODEN,IDX,FSTOIC,HFU,CP, COMMON   15
         1 GASCON,RHOCON,UNICON,PRESS,NVFAV,TCYLW,TINLW,TLIP,ACOEF(4),    COMMON   16
         2 T4,DFAC,WFU,WCO2,WCO,WOX,WH2O,WN2,NYY,CXX,RATIO1,RATIO2,       COMMON   17
         3 RATIO3,RATIO4,HCO,TAN,ITWALL                                   COMMON   18
          COMMON/CTDMA/KEND,ICTDMA(13)                                    COMMON   19
          KONTRO=NV-LVRX+1                                                STR       6
          GO TO (100,200,300),KONTRO                                      STR       7
C     ------    X-DIRECTION FLUX    ------                                STR       8
  100     CONTINUE                                                        STR       9
          DO 101 K=2,N                                                    STR      10
          NVKM=NVM(NVRX)+KM(K)                                            STR      11
          CALL SORAD                                                      STR      12
          CALL SOMOD                                                      STR      13
          DO 102 J=2,M                                                    STR      14
          TX=0.                                                           STR      15
          IS=IWLI(J,NGOTO)                                                STR      16
          IE=IWLO(J,NGOTO)                                                STR      17
          DO 103 I=IS,IE                                                  STR      18
          LIJ=JM(J)+I                                                     STR      19
          LP=LIJ+KM(K)                                                    STR      20
          LXP=LP+1                                                        STR      21
          AXM(LIJ)=TX                                                     STR      22
          TX=.5*(GAM(LP)+GAM(LXP))/XDIF(I+1)                              STR      23
          AXP(LIJ)=TX                                                     STR      24
          SU(LIJ)=SU(LIJ)*XS(I)                                           STR      25
          SP(LIJ)=SP(LIJ)*XS(I)                                           STR      26
  103     CONTINUE                                                        STR      27
          AXP(LIJ)=0.                                                     STR      28
  102     CONTINUE                                                        STR      29
          DO 104 J=2,M                                                    STR      30
          LPF=NVKM+JM(J)                                                  STR      31
          IS=IWLI(J,NGOTO)                                                STR      32
          IE=IWLO(J,NGOTO)                                                STR      33
          ISTPI=IS-1                                                      STR      34
          A(ISTPI)=0.                                                     STR      35
          B(ISTPI)=0.                                                     STR      36
          DO 105 I=IS,IE                                                  STR      37
          LIJ=JM(J)+I                                                     STR      38
          STORE=AXP(LIJ)+AXM(LIJ)-SP(LIJ)-AXM(LIJ)*A(I-1)                 STR      39
          A(I)=AXP(LIJ)/STORE                                             STR      40
  105     B(I)=(SU(LIJ)+AXM(LIJ)*B(I-1))/STORE                            STR      41
          ISUM=IS+IE                                                      STR      42
          DO 106 II=IS,IE                                                 STR      43
          I=ISUM-II                                                       STR      44
          LP=LPF+I                                                        STR      45
  106     F(LP)=A(I)*F(LP+1)+B(I)                                         STR      46
  104     CONTINUE                                                        STR      47
  101     CONTINUE                                                        STR      48
          RETURN                                                          STR      49
C     ------    Y-DIRECTION FLUX    ---                                   STR      50
  200     CONTINUE                                                        STR      51
          DO 201 K=2,N                                                    STR      52
```

```
      NZKM=NUM(NZBT)+M(K)                                        STR   53
      CALL SORAD                                                 STR   54
      CALL SOMOD                                                 STR   55
      DO 202 I=2,L                                               STR   56
      TY=0.                                                      STR   57
      JS=JML1(I,NGOTO)+1                                         STR   58
      JE=JML2(I,NGOTO)-1                                         STR   59
      DO 203 J=JS,JE                                             STR   60
      LIJ=JM(J)+I                                                STR   61
      LP=LIJ+KM(K)                                               STR   62
      LYP=LP+NI                                                  STR   63
      AYM(LIJ)=TY                                                STR   64
      TY=.5*(GAM(LP)+GAM(LYP))/YDIF(J+1)*RM(J+1)                 STR   65
      AYP(LIJ)=TY                                                STR   66
      SU(LIJ)=SU(LIJ)*YS(J)*R(J)                                 STR   67
      SP(LIJ)=SP(LIJ)*YS(J)*R(J)                                 STR   68
  203 CONTINUE                                                   STR   69
      AYP(LIJ)=0.                                                STR   70
  202 CONTINUE                                                   STR   71
      DO 204 I=2,L                                               STR   72
      LPF=NZKM+I                                                 STR   73
      JS=JML1(I,NGOTO)+1                                         STR   74
      JE=JML2(I,NGOTO)-1                                         STR   75
      JSTR1=JS-1                                                 STR   76
      A(JSTR1)=0.                                                STR   77
      B(JSTR1)=0.                                                STR   78
      DO 205 J=JS,JE                                             STR   79
      LIJ=JM(J)+I                                                STR   80
      STORE=AYP(LIJ)+AYM(LIJ)-SP(LIJ)-AYM(LIJ)*A(J-1)            STR   81
      A(J)=AYP(LIJ)/STORE                                        STR   82
  205 B(J)=(SU(LIJ)+AYM(LIJ)*B(J-1))/STORE                       STR   83
      JSUM=JS+JE                                                 STR   84
      DO 206 JJ=JS,JE                                            STR   85
      J=JSUM-JJ                                                  STR   86
      LP=LPF+JM(J)                                               STR   87
      LYP=LP+NI                                                  STR   88
  206 F(LP)=A(J)*F(LYP)+B(J)                                     STR   89
  204 CONTINUE                                                   STR   90
  201 CONTINUE                                                   STR   91
      RETURN                                                     STR   92
C ------      Z-DIRECTION FLUX    ---                              STR   93
  305 KSUM=2+N                                                   STR   94
      DO 301 J=2,M                                               STR   95
      JPLANE=J                                                   STR   96
      NYJM=NUM(NCBZ)+JM(J)                                       STR   97
      CALL SORAD                                                 STR   98
      IS=IML1(J,NGOTO)                                           STR  100
      IE=IML2(J,NGOTO)                                           STR  101
      DO 302 I=IS,IE                                             STR  102
      LIJ=JM(J)+I                                                STR  103
      TZ=0.                                                      STR  104
      DO 303 K=2,N                                               STR  105
      LIK=JM(K)+I                                                STR  106
      LP=LIJ+KM(K)                                               STR  107
      LZP=LP+NIJ                                                 STR  108
      AZM(LIK)=TZ                                                STR  109
      TZ=.5*(GAM(LP)+GAM(LZP))/(ZDIF(K+1)*R(J))                  STR  110
      AZP(LIK)=TZ                                                STR  111
      SU(LIK)=SU(LIK)*ZS(K)*R(J)                                 STR  112
      SP(LIK)=SP(LIK)*ZS(K)*R(J)                                 STR  113
  303 CONTINUE                                                   STR  114
      AZP(LIK)=0.                                                STR  115
  302 CONTINUE                                                   STR  116
      CALL SOMODZ
      DO 304 I=IS,IE                                             STR  117
      A(1)=0.                                                    STR  118
      B(1)=0.                                                    STR  119
      LPF=NYJM+I                                                 STR  120
      DO 305 K=2,N                                               STR  121
      LIK=JM(K)+I                                                STR  122
      STORE=AZP(LIK)+AZM(LIK)-SP(LIK)-AZM(LIK)*A(K-1)            STR  123
      A(K)=AZP(LIK)/STORE                                        STR  124
  305 B(K)=(SU(LIK)+AZM(LIK)*B(K-1))/STORE                       STR  125
      DO 306 KK=2,N                                              STR  126
      K=KSUM-KK                                                  STR  127
      LP=LPF+KM(K)                                               STR  128
      LZP=LP+NIJ                                                 STR  129
```

```
      SUBROUTINE STRAD        73/74   OPT=0 TRACE                           FTN 4.6+430        08/24/78  14.08.46        PAGE     3

 155                300 F(LP)=A(K)*F(LZP)+B(K)
                    304 CONTINUE
                    301 CONTINUE                                                                 STR        130
                        RETURN                                                                   STR        131
                        END                                                                      STR        132
                                                                                                 STR        133
                                                                                                 STR        134

 CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

     32      I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
     35      I                 CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
     77      I                 CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
    129      I                 CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
    146      I                 CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
```

```
      SUBROUTINE SOLVE                                                 SO       2
      COMMON/COEF/AP(40),BP(40),FP(30),GP(30),APP(30),BPP(30)          SO       3
      COMMON F(3500),DU(500),DV(500),DW(500),                          COMF8    2
     1  RHO(500),VISC(500),SU(100),SP(100),DPMODP(500),                COMF8    3
     1  AXP(100),AXM(100),AYP(100),AYM(100),AZP(100),                  COMF8    4
     2  AZM(100),CZ(100),CY(10),CZU(100),CYU(10),                      COMF8    5
     3  CZP(100),CYP(10),JING(100),NTP1,NTP2                           COMF8    6
      DIMENSION U(500),V(500),W(500),PP(500),P(500),TEMP(500)          COMF8    7
      DIMENSION GAM(500)                                               COMF8    8
      EQUIVALENCE (F(1),U(1)),(F(501),V(1)),(F(1001),W(1))             COMF8    9
      EQUIVALENCE (F(1501),PP(1)),(F(2001),P(1)),(F(2501),TEMP(1))     COMF8   10
      EQUIVALENCE (F(3001),GAM(1))                                     COMF8   11
      COMMON/CYL/R(30),RV(30),RMV(30),YSR(30),YSVR(30),IPLAX           COMMON   2
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),      COMMON   3
     1  YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),    COMMON   4
     2  FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME                        COMMON   5
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NI,NJ,NK,NINJ,NINJNK,NV, COMMON   6
     1  NNV,NGOTO,K,ISTR,JSTR,KSTR,NVM(20),KM(30),JM(30),ISTEP,        COMMON   7
     2  ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISWP,JSWP,RELAX(16),NP, COMMON   8
     3  NRHO,NGAM,IWLI(30,5),IWLO(30,5),JWLO(40,5),JWLI(40,5),IWEI,    COMMON   9
     4  IWEO,MM1,JWII,JWIO,JWOI,JWOO,IOW,JKIN(30,30),IKIN(40,30)       COMMON  10
      COMMON/INDEX/IPAR,LPREF,ISTUN,INCOMP,ITRAD,NVRX,NVRY,NVRZ,JPLANE COMMON  11
     1  ,PLAXM1,LVK,LVD,LVFUOX,LVFU,LVCO,LVH,LVRX,LVRY,LVRZ,NVF(13),   COMMON  12
     2  IJUMP,IRES,TITLE2(20),IMAX,JMAX,KMAX,NVCO,FUNCO,NVH2O,NVCO2,   COMMON  13
     3  NVN2                                                           COMMON  14
      COMMON/THERM/NVH,NVFU,NVOX,NVFUOX,NVTE,MODEN,IOK,FSTOIC,HFU,CP,  COMMON  15
     1  GASCON,RHOCON,UNICON,PRESS,NVFAV,TCYLW,TIMLW,TLIF,ACOEF(4),    COMMON  16
     2  T4,DFAC,WFU,WCO2,WCO,WOX,WH2O,WN2,HYY,CXX,RATIO1,RATIO2,       COMMON  17
     3  RATIO3,RATIO4,WCO,TAM,ITWALL                                   COMMON  18
      COMMON/CTOMA/KEND,ICTOMA(13)                                     COMMON  19
      ENTRY SOLVE1                                                     SO       7
      RELAXM=1.-RELAX(NV)                                              SO       8
      DO 10 J=JSTR,M                                                   SO       9
      KJM=KM(K)+JM(J)                                                  SO      10
      IS=IWLI(J,NGOTO)                                                 SO      11
      IE=IWLO(J,NGOTO)                                                 SO      12
      DO 10 I=IS,IE                                                    SO      13
      LIJ=JM(J)+I                                                      SO      14
      LP=KJM+I                                                         SO      15
      LPF=LP+NVM(NVF(NV))                                              SO      16
      LZP=LPF+NINJ                                                     SO      17
      LZM=LPF-NINJ                                                     SO      18
      FLZP=F(LZP)                                                      SO      19
      IF (NV.EQ.3.AND.K.EQ.NP1) FLZP=W(LIJ+2*NINJ)                     SO      20
   15 CONTINUE                                                         SO      21
      SP(LIJ)=(AXP(LIJ)+AXP(LIJ)+AYM(LIJ)+AYP(LIJ)+AZM(LIJ)+AZP(LIJ)-  SO      22
     1SP(LIJ))/RELAX(NV)                                               SO      23
      SU(LIJ)=SU(LIJ)+SP(LIJ)*RELAXM*F(LPF)+AZM(LIJ)*F(LZM)+AZP(LIJ)*  SO      24
     1  FLZP                                                           SO      25
      GO TO (11,12,13,10),NGOTO                                        SO      26
   11 DU(LP)=DU(LP)/SP(LIJ)                                            SO      27
      GO TO 10                                                         SO      28
   12 DV(LP)=DV(LP)/SP(LIJ)                                            SO      29
      GO TO 10                                                         SO      30
   13 DW(LP)=DW(LP)/SP(LIJ)                                            SO      31
   10 CONTINUE                                                         SO      32
      NVKM=KM(K)+NVM(NVF(NV))                                          SO      33
      ISUM=ISTR+L                                                      SO      34
      JSUM=JSTR+M                                                      SO      35
      INOMAX=ICTOMA(NV)                                                SO      36
      DO 45 INO=1,INOMAX                                               SO      37
      GO TO (20,30),IXY                                                SO      38
   20 CONTINUE                                                         SO      39
      DO 21 JJ=JSTR,M                                                  SO      40
      GO TO (24,25),JSWP                                               SO      41
   24 J=JJ                                                             SO      42
      GO TO 26                                                         SO      43
   25 J=JSUM-JJ                                                        SO      44
   26 CONTINUE                                                         SO      45
      LPF=NVKM+JM(J)                                                   SO      46
      IS=IWLI(J,NGOTO)                                                 SO      47
      IE=IWLO(J,NGOTO)                                                 SO      48
      ISTR1=IS-1                                                       SO      49
      LPF1=LPF+ISTR1                                                   SO      50
      AP(ISTR1)=0.                                                     SO      51
      BP(ISTR1)=F(LPF1)                                                SO      52
      DO 22 I=IS,IE                                                    SO      53
```

```
      LIJ=JM(J)+I
      LYP=LPF+NI+I
      LYM=LPF-NI+I
      STORE=SP(LIJ)-AXM(LIJ)*AP(I-1)+1.E-30
      AP(I)=AXP(LIJ)/STORE
22    BP(I)=(SU(LIJ)+AYP(LIJ)*F(LYP)+AYM(LIJ)*F(LYM)+AXM(LIJ)*BP(I-1))/
     1STORE
      ISUM1=IS+IE
      DO 23 II=IS,IE
      I=ISUM1-II
      LP=LPF+I
23    F(LP)=AP(I)*F(LP+1)+BP(I)
21    CONTINUE
      JSWP=3-JSWP
      GO TO (28,20),JSWP
   28 CONTINUE
      GO TO (30,40),IXY
30    DO 31 II=ISTR,L
      GO TO (34,35),ISWP
34    I=II
      GO TO 36
35    I=ISUM-II
36    CONTINUE
      LPF=NVEM+I
      JS=JMLI(I,NGOTO)+1
      JE=JMLO(I,NGOTO)-1
      JSTR1=JS-1
      LPF1=LPF+JM(JSTR1)
      AP(JSTR1)=0.
      BP(JSTR1)=F(LPF1)
      DO 32 J=JS,JE
      LIJ=JM(J)+I
      LXP=NVEM+LIJ+I
      LXM=LXP-2
      STORE=SP(LIJ)-AYM(LIJ)*AP(J-1)+1.E-30
      AP(J)=AYP(LIJ)/STORE
32    BP(J)=(SU(LIJ)+AXP(LIJ)*F(LXP)+AXM(LIJ)*F(LXM)+AYM(LIJ)*BP(J-1))/
     1STORE
      JSUM1=JS+JE
      DO 33 JJ=JS,JE
      J=JSUM1-JJ
      LP=LPF+JM(J)
      LYP=LP+NI
33    F(LP)=AP(J)*F(LYP)+BP(J)
31    CONTINUE
      ISWP=3-ISWP
      GO TO (38,30),ISWP
   38 CONTINUE
      GO TO (40,20),IXY
40    CONTINUE
   45 CONTINUE
      RETURN
C  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  **  *
      ENTRY SOLVE2
      RETURN
      END
```

CARD NR.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
62	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
65	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
92	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
94	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
96	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
124	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
126	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.

```
      SUBROUTINE FPRINT (ISTRT,ISTOP,NVVV)                                   FP        2
      COMMON F(3500),DU(500),DV(500),DW(500),                                COMFB     2
     1 RHO(500),VISC(500),SU(100),SP(100),DRHODP(500),                       COMFB     3
     1 AXP(100),AXM(100),AYP(100),AYM(100),AZP(100),                         COMFB     4
     2 AZM(100),CZ(100),CY(10),CZU(100),CYU(10),                             COMFB     5
     3 CZP(100),CYP(10),JEVC(100),NTP1,NTP2                                  COMFB     6
      DIMENSION U(500),V(500),W(500),PP(500),P(500),TEMP(500)                COMFB     7
      DIMENSION GAM(500)                                                     COMFB     8
      EQUIVALENCE (F(1),U(1)),(F(501),V(1)),(F(1001),W(1))                   COMFB     9
      EQUIVALENCE (F(1501),PP(1)),(F(2001),P(1)),(F(2501),TEMP(1))           COMFB    10
      EQUIVALENCE (F(3001),GAM(1))                                           COMFB    11
      COMMON/CYL/R(30),RM(30),RMV(30),YSP(30),YSVP(30),IPLAT                 COMMON    2
      COMMON/GRID/X(40),Y(30),Z(30),XS(40),YS(30),ZS(30),XSU(40),            COMMON    3
     1 YSV(30),ZSW(30),XDIF(40),YDIF(30),ZDIF(30),FXP(40),FXM(40),           COMMON    4
     2 FYP(30),FYM(30),FZP(30),FZM(30),DT,TIME                               COMMON    5
      COMMON/INT/L,M,N,LCV,MCV,NCV,LP1,MP1,NP1,NI,NJ,NK,NINJ,NINJNK,NV,      COMMON    6
     1 NNV,NSOTO,K,ISTR,JSTR,KSTR,NVM(20),KM(30),JM(30),ISTEP,              COMMON    7
     2 ISOLVE(13),IPRINT(22),TITLE(10,22),IXY,ISWP,JSWP,RELAX(16),MP,       COMMON    8
     3 NPRO,NSAM,IWLI(30,5),IWLO(30,5),JWLO(40,5),JWLI(40,5),IWEI,          COMMON    9
     4 IWEO,NNI,JWII,JWIO,JWOI,JWOO,IJW,JWIN(30,30),IKIN(40,30)              COMMON   10
      COMMON/INDEX/IPAR,LPREF,ISTUN,INCOMP,ITRAD,NVPX,NVPY,NVPZ,JPLANE       COMMON   11
     1 ,PLANEI,LVK,LVD,LVFUDX,LVFU,LVCO,LVH,LVPX,LVPY,LVPZ,NVF(13),          COMMON   12
     2 IJUMP,IRES,TITLE2(20),IMAX,JMAX,KMAX,NVCO,FUMCO,NVH2O,NVCO2,          COMMON   13
     3 NVN2                                                                  COMMON   14
      COMMON/THERM/NVH,NVFU,NVOX,NVFUOX,NVTE,MODFN,IOX,FSTOIC,HFU,CP,        COMMON   15
     1 GASCON,RHOCON,UNICON,PRESS,NVFAV,TCYLW,TINLW,TLIP,ACOEF(4),          COMMON   16
     2 T4,OFAC,WFU,WCO2,WCO,W3F,WH2O,WN2,HYT,CXX,RATIO1,RATIO2,             COMMON   17
     3 RATIO3,RATIO4,HCO,TAN,ITWALL                                          COMMON   18
      COMMON/CTOMA/KEND,ICTOMA(13)                                           COMMON   19
      DIMENSION INVV(22)                                                     FP        5
      DATA INVV/2,1,1,3,1,1,4,4,4,1,1,1,1,1,4,1,1,1,1,1,1,5/                FP        6
      NVVV=NVVV-1                                                            FP        7
      DO 108 NV=ISTRT,ISTOP                                                  FP        8
      NVVV=NVVV+1                                                            FP        9
      IF (IPRINT(NVVV).EQ.0) GO TO 108                                       FP       10
      WRITE (6,101) (TITLE(I,NVVV),I=1,10)                                   FP       11
  101 FORMAT (1H0,20(2H*-),10A6,3X,20(2H-*))                                 FP       12
      KONE=1                                                                 FP       13
      IF (NVV.EQ.3) KONE=2                                                   FP       14
      NSKIP=IPRINT(NVV)                                                      FP       15
      DO 109 K=KONE,MP1,NSKIP                                                FP       16
      WRITE(6,102) K                                                         FP       17
  102 FORMAT(1H0,58X,4HK = ,I2)                                              FP       18
      NKM=NVM(NV)+KM(K)                                                      FP       19
      JONE=1                                                                 FP       20
      IF (NVV.EQ.2) JONE=2                                                   FP       21
      IONE=1                                                                 FP       22
      IF (NVV.EQ.1) IONE=2                                                   FP       23
      ISTART=IONE-12                                                         FP       24
  105 CONTINUE                                                               FP       25
      ISTART=ISTART+12                                                       FP       26
      IEND=ISTART+11                                                         FP       27
      IEND=MIN0(IEND,LP1)                                                    FP       28
      WRITE(6,103) (I,I=ISTART,IEND)                                         FP       29
  103 FORMAT(1H0,6H  I = ,I3,11I10)                                          FP       30
      WRITE(6,104)                                                           FP       31
  104 FORMAT(2H J)                                                           FP       32
      JSUM=JONE+MP1                                                          FP       33
      DO 106 JJ=JONE,MP1                                                     FP       34
      J=JSUM-JJ                                                              FP       35
      LPF=NKM+JM(J)                                                          FP       36
      LPL=LPF+IEND                                                           FP       37
      LPF=LPF+ISTART                                                         FP       38
  106 WRITE(6,107) J,(F(LP),LP=LPF,LPL)                                      FP       39
  107 FORMAT(I3,1P12E10.2)                                                   FP       40
      IF(IEND.LT.LP1) GO TO 105                                              FP       41
  109 CONTINUE                                                               FP       42
  108 CONTINUE                                                               FP       43
      RETURN                                                                 FP       44
      END                                                                    FP       45
```

```
CARD NR. SEVERITY  DETAILS     DIAGNOSIS OF PROBLEM

   33     I                    CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
```

```
CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM
   41       I                 CONTROL VARIABLE IN COMMON OR EQUIVALENCED, OPTIMIZATION MAY BE INHIBITED.
```

APPENDIX D

LISTING OF LINER COOLING MODEL


```
      PROGRAM MAIN (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)                MA       2
C                                                                         MA       3
C     ***************************************************************    MA       4
C     ***************************************************************    MA       5
C     ****************** COMBUSTOR DESIGN CRITERIA ******************    MA       6
C     WALL COOLING MODEL                                                  MA       7
C                                                                         MA       8
C                                                                         MA       9
C     ---------------------------------------------------------------    MA      10
CHAPTER0000000000000000000  PRELIMINARIES  00000000000000000000000000    MA      11
C     --------------------------- DIMENSIONS AND COMMON BLOCKS.           MA      12
      COMMON/COMA/A(43),AJE(16),AJI(16),B(43),C(43),CSALFA,C(43),         COMA     2
     1 DPDX(43),DX,EMU(43),F(15,43),FS(3,43),TAT,TEND,TFIN,INDE(16),      COMA     3
     2 INDI(16),IOUT,ISTEP,ITEST,IUTRAP,JS,JSW,JV,JY,KEX,KIN,KPAD,N,      COMA     4
     3 MDZ,NF,NOVEL,NP1,NP2,NP3,OM(43),OMD(43),P(43),PEI,PR(16),          COMA     5
     4 PREF(16),PSIE,PSII,R(43),RHO(43),RU(43),RMF,RMI,SD(43),SU(43),     COMA     6
     5 TAUE,TAUI,U(43),XD,XU,Y(43),YE,YI,PS4RL(43),RDY(43),ISOLVE(36),    COMA     7
     6 US(43),AMU(43),SUM1,SUM2,SUM3,SUM4,PIGSCN,FDIFI(16),FDIFF(16),     COMA     8
     7 GE(16),GI(16),JLOC(12),W(12),JH,JFU,JCO2,JCO,JOX,JH2O,JOH,JO,JHS,  COMA     9
     8 JH2,JN,JNO,JN2,JVT,JO,JK,JT,JRY,NSP,NSPM,ABSMP,SCATR,BOM(200),     COMA    10
     9 EMI,SIGMA,CP,JFUOX,IFLUX,EVAP(43),TEJEL,MEN7                       COMA    11
      COMMON/COMB/AM,ALMG,EWALL,FP,M,MFU,INERT,MASSTP,MODEL,PRESS,        COMB     2
     1 UBAP,UFAC,C1,C2,CD,C2VT,AKFAC,ALFAC,ARCON1,ARCON2,PREXP1,CD75,     COMB     3
     2 PREXP2,CR1,CR2,MODEP,MODCP,RATIO1,RATIO2,RATIO3,RATIO4,RATIO5,     COMB     4
     3 CX,HY,DXOLD,WFU,WCO2,WCO,WOX,WH2O,WOH,WO,WH,                       COMB     5
     4 WH2,WN,WNO,WN2                                                     COMB     6
      COMMON/COMC/API(40),AFE(40),XR(40),NRP                              COMC     2
      COMMON/COMD/XUINJ(12),UINJ(12),TUINJ(12),VTUINJ(12),AUINJ(12),      COMD     2
     1 XVINJ(12),UVINJ(12),VINJ(12),VTVINJ(12),TVINJ(12),AVINJ(12),       COMD     3
     2 RUINJ(12),APUINJ(12),HJINJ(12),XLUINJ(12),TAN(2),VELA(2),          COMD     4
     3 PRAD(2),NUI,NUE,NVI,NVE                                            COMD     5
      DIMENSION TITLE(24),OUT(43),LAB(2)                                  MA      17
      DIMENSION XPLOT(43),YPLOT(10,43),YAXES(10,2),SYMBOL(10)             MA      18
      DIMENSION FLUX(16),DFI(16),DFE(16),AJTD(16),AJFD(16)                MA      19
      DIMENSION YIN(40),UIN(40),VTIN(40),TIN(40),MFUIN(40),MCOIN(40)      MA      20
      DIMENSION TNIN(40),TLIN(40),MCO2IN(40),MH2IN(40)                    MA      21
      DIMENSION MFUOXIN(40)                                               MA      22
      DIMENSION IPLOT(19),IPRNT(19),SYM(19),LAB1(19),LAB2(19)             MA      23
      REAL MFUIN,MCOIN,MCO2IN,LAB,LAB1,LAB2,MH2IN,MFUOXIN                 MA      24
      NAMELIST/INPUT/IUTRAP,ULIM,PEILIM,AFAC,AEXOLM,POWER,NOVEL,          MA      25
     1 ARCON1,PREXP1,CR1,ARCON2,PREXP2,CR2,CP,IOPDX,C1,C2,CD,             MA      26
     2 C2VT,AKFAC,ALFAC,PREF,CX,HY,MFU,MODEP,ITHIN,KCFAC,URAT,            MA      27
     3 ABSOP,SCATR,EMISW                                                  MA      28
      DATA JH,JFU,JCO2,JCO,JOX,JH2O,JOH,JO,JHS/1,2,3,4,5,6,7,8,9/         MA      29
      DATA JH2,JN,JNO,JVT,JK,JP,JN2,JT,JRY/10,11,12,13,14,15,1,2,3/       MA      30
      DATA JFUOX/16/                                                      MA      31
      DATA IPLOT/0,1,0,1,1,0,0,0,0,0,0,0,1,0,0,1,0,1,0/                   MA      32
      DATA SYM/1HE,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H*,1H+,           MA      33
     1 1HY,1HD,1HK,1HP,1H.,1HT,1HR/                                       MA      34
      DATA LAB1/6HENTH ,6HFUEL ,5HCO2 ,5HCO ,6HOXYGEN,6HH2O ,             MA      35
     1 6HOH ,6HO ,6HH ,6HH2 ,5HN ,6HNO ,6HVT ,                            MA      36
     2 6HKE ,6HLEN ,6HPHT ,6HN2 ,6HTEMP ,6HRAD /                          MA      37
      DATA LAB2/19*2H /                                                   MA      38
      DATA W/16.,44.,28.,32.,18.,17.,16.,1.,2.,14.,30.,28./               MA      39
      DATA WFU,WCO2,WCO,WOX,WH2O,WOH,WO,WH,WH2,WN,WNO,WN2/16.,44.,28.,    MA      40
     1 32.,18.,17.,16.,1.,2.,14.,30.,28./                                 MA      41
      DATA SUM1,SUM2,SUM3,SUM4/0.,0.,0.,0./                               MA      42
C                                                                         MA      43
      READ(5,1) TITLE                                                     MA      44
    1 FORMAT(12A6)                                                        MA      45
C                                                                         MA      46
C     ---------------------------------------------------------------    MA      47
CHAPTER1111111111111111111  PARAMETERS AND CONTROL INDICES  1111111111111 MA      48
      READ (5,2) N,KPAD,MASSTP,ISMPL,MODEL,INERT,IFLUX,ITEMP              MA      49
    2 FORMAT (8(I2,8X))                                                   MA      50
      READ (5,3) NSTAT,NPROF,NPLOT,ITEST,LASTEP                           MA      51
    3 FORMAT (8(I5,5X))                                                   MA      52
      IUTRAP=2                                                            MA      53
      ULIM=.05                                                            MA      54
      PEILIM=.01                                                          MA      55
      AFAC=.2                                                             MA      56
      AEXOLM=.02                                                          MA      57
      CSALFA=1.                                                           MA      58
      IOPDX=1                                                             MA      59
      M=.9                                                                MA      60
      AK=.435                                                             MA      61
      ALMG=.09                                                            MA      62
```

```
      FP=.033
      UFAC=.01
      NOVEL=2
      ITHIN=1
      KREAD=0
      UPAT=.83
      ABSOR=.1
      SCATR=.01
      EMISW=.8
C     -----------------------------------------------------------------
CHAPTER22222222222222222222222  GRID AND GEOMETRY  2222222222222222222
      READ (5,4) XU,XULAST,FRR,XEND,XOUT,PRESS,POWER
      READ (5,2) NBP
      READ (5,4) (XB(I),ARI(I),ARE(I),I=1,NBP)
      RI=TAB(XU,XB,ARI,NBP)
      RE=TAB(XU,XB,ARE,NBP)
      READ (5,4) PA,PB,PD
    4 FORMAT (8E10.4)
C     ----- P(I) ADJUSTMENT MADE JUST BEFORE CALL STRIDE(1).
C     ---------STRIDE4----------STRIDE4----------STRIDE4--------STRIDE4
      CALL STRIDE(4)
      IF(XEND.EQ.0.) IEND=0
      IF(XOUT.EQ.0.) IOUT=0
C     ------------------- CHANGE IEND, IAX AND IOUT, IF NECESSARY.
      DO 20 I=2,NP2
   20 OUT(I)=(FLOAT(I-2)/FLOAT(N))**ABS(POWER)
      IF (POWER.GT.0.0) GO TO 22
      DO 24 I=2,NP2
      II=NP2+2-I
   24 Y(II)=1.0-OUT(I)
      GO TO 26
   22 DO 28 I=2,NP2
   28 Y(I)=OUT(I)
   26 CONTINUE
C
C     -----------------------------------------------------------------
CHAPTER33333333333333333333333  DEPENDENT VARIABLES SELECTION  3333333
C
      ISOLVE(JH)=ITEMP
      ISOLVE(JFU)=MASSTR
      ISOLVE(JCO2)=0
      ISOLVE(JCO)=MASSTR
      ISOLVE(JOX)=0
      ISOLVE(JH2O)=0
      ISOLVE(JOH)=0
      ISOLVE(JO)=0
      ISOLVE(JHS)=0
      ISOLVE(JH2)=0
      ISOLVE(JN)=0
      ISOLVE(JNO)=0
      ISOLVE(JVT)=ISWPL
      ISOLVE(JK)=MODEL-1
      ISOLVE(JD)=MODEL-1
      ISOLVE(JFUOX)=MASSTR
      NF=16
      NFS=3
      IPRNT(JH)=0
      IPRNT(JFU)=MASSTR
      IPRNT(JCO)=MASSTR
      IPRNT(JVT)=ISWPL
      IPRNT(JK)=MODEL-1
      IPRNT(JD)=MODEL-1
      IPRNT(JFUOX)=MASSTR
      IPRNT(JCO2)=0
      IPRNT(JOX)=MASSTR
      IPRNT(JH2O)=0
      IPRNT(JOH)=0
      IPRNT(JO)=0
      IPRNT(JHS)=0
      IPRNT(JH2)=0
      IPRNT(JN)=0
      IPRNT(JNO)=0
      INDX=NF
      IPRNT(JN2+INDX)=0
      IPRNT(JT+INDX)=ITEMP
      IPRNT(JRY+INDX)=IFLUX
```

```
      NSP=12
      NSPM=NSP-1
      JLOC(1)=JFU
      JLOC(2)=JCO2
      JLOC(3)=JCO
      JLOC(4)=JOX
      JLOC(5)=JH2O
      JLOC(6)=JOH
      JLOC(7)=JO
      JLOC(8)=JHS
      JLOC(9)=JH2
      JLOC(10)=JN
      JLOC(11)=JNO
      JLOC(12)=JN2
C
C ------------------------------------------------------------------------
CHAPTER4444444444444444444444444444  MATERIAL CONSTANTS  444444444444444
C                                      S.I. UNITS
      GASCON=8314.
      WMIX=28.84
      CP=1046.
      CX=1.0
      HY=4.
      HFU=-49317.
C     ---ARRCON IS ACTIVATION ENERGY DIVIDED BY UNIVERSAL GAS CONSTANT.
      PREXP1=5.E+15
      ARCON1=26503.
      CP1=6.0
      PREXP2=6.E+09
      ARCON2=12503.
      CR2=4.0
      MCLER=2
C
      DO 40 J=1,NF
      PR(J)=.7
      PREF(J)=.86
   40 IF (MODEL.EQ.1) PREF(J)=PR(J)
      PREF(JVT)=1.0
C     -----   TURBULENCE CONSTANTS    ------ ----
      C1=1.42
      C2=1.92
      CD=.09
      AMFAC=.03
      ALFAC=.02
      C2VT=0.36
      PREF(JM)=1.0
C     ---------     NAMELIST    -------
      READ (5,INPUT)
      PREF(JD)=AK**2/((C2-C1)/SQRT(CD))
      CD75=CD**.75
      GAMMA=CP/(CP-GASCON/WMIX)
      PCRSCN=PRESS*WMIX/GASCON
      WFU=12.*CX+HY
      W(1)=WFU
      RATIO1=WOX*(CX+HY/4.)/WFU
      RATIO2=.232
      RATIO3=WOX*0.5/WCO
      RATIO4=WCO*CX/WFU
      SLW=1./(1.-URAT)-1.
      DUM=COEF(WFU,1)
      DUM=COEF(HFU,1)
      EPI=EMISW/(2.-EMISW)
C
C ------------------------------------------------------------------------
CHAPTER5555555555555555555555555555  INITIAL CONDITIONS  5555555555
      READ (5,4) UA,UD,VTA,VTD
      READ (5,4) F2A,F2D,TA,TD,TWALL
C
      FIA=F2A*HOR(TA,1)+(1.-F2A)*RATIO2*HOR(TA,4)+(1.-F2A)*(1.-RATIO2)*
     1   HOR(TA,12)+.5*UA*UA
      FID=F2D*HOR(TD,1)+(1.-F2D)*RATIO2*HOR(TD,4)+(1.-F2D)*(1.-RATIO2)*
     1   HOR(TD,12)+.5*UD*UD
      READ (5,2) KIN,NUI,NUE,NWT,NWF
      READ (5,4) (YIN(I),I=1,NIN)
      READ (5,4) (JIN(I),I=1,NIN)
      READ (5,4) (VTIN(I),I=1,NIN)
      READ (5,4) (TIN(I),I=1,NIN)
```

```
      READ (5,4) (PFUIN(I),I=1,NIN)
      READ (5,4) (PFUCXIN(I),I=1,NIN)
      READ (5,4) (PCBIN(I),I=1,NIN)
      IF (KREAD.EQ.0) GO TO 19
      READ (5,4) (TEIN(I),I=1,NIN)
      READ (5,4) (TLIN(I),I=1,NIN)
   19 CONTINUE
C
C ------------ READ INJECTION VALUES
      IF (NUI.LE.0) GO TO 30
      READ (5,4) (XUINJ(I),I=1,NUI)
      READ (5,4) (XLUINJ(I),I=1,NUI)
      READ (5,4) (UINJ(I),I=1,NUI)
      READ (5,4) (VTUINJ(I),I=1,NUI)
      READ (5,4) (TUINJ(I),I=1,NUI)
      READ (5,4) (AUINJ(I),I=1,NUI)
      READ (5,4) (HUINJ(I),I=1,NUI)
      READ (5,4) (APUINJ(I),I=1,NUI)
      DO 31 I=1,NUI
      DEN=PDESCN/TUINJ(I)
   31 RUINJ(I)=DEN*UINJ(I)
   30 NI=NUI+1
      XUINJ(NI)=2.*ABS(XULAST)
      XLUINJ(NI)=2.*ABS(XULAST)
      NI=NI+1
      IF (NUE.LE.0) GO TO 32
      NE=NI+NUE-1
      READ (5,4) (XUINJ(I),I=NI,NE)
      READ (5,4) (XLUINJ(I),I=NI,NE)
      READ (5,4) (UINJ(I),I=NI,NE)
      READ (5,4) (VTUINJ(I),I=NI,NE)
      READ (5,4) (TUINJ(I),I=NI,NE)
      READ (5,4) (AUINJ(I),I=NI,NE)
      READ (5,4) (HUINJ(I),I=NI,NE)
      READ (5,4) (APUINJ(I),I=NI,NE)
      DO 33 I=NI,NE
      DEN=PDESCN/TUINJ(I)
   33 RUINJ(I)=DEN*UINJ(I)
   32 NE=NI+NUE
      XUINJ(NE)=2.*ABS(XULAST)
      XLUINJ(NE)=2.*ABS(XULAST)
      NUE=NUI+2
      NUI=1
      IF (NVI.LE.0) GO TO 35
      READ (5,4) (XVINJ(I),I=1,NVI)
      READ (5,4) (UVINJ(I),I=1,NVI)
      READ (5,4) (VINJ(I),I=1,NVI)
      READ (5,4) (VTVINJ(I),I=1,NVI)
      READ (5,4) (TVINJ(I),I=1,NVI)
      READ (5,4) (AVINJ(I),I=1,NVI)
   35 NI=NVI+1
      XVINJ(NI)=2.*ABS(XULAST)
      NI=NI+1
      IF (NVE.LE.0) GO TO 36
      NE=NI+NVE-1
      READ (5,4) (XVINJ(I),I=NI,NE)
      READ (5,4) (UVINJ(I),I=NI,NE)
      READ (5,4) (VINJ(I),I=NI,NE)
      READ (5,4) (VTVINJ(I),I=NI,NE)
      READ (5,4) (TVINJ(I),I=NI,NE)
      READ (5,4) (AVINJ(I),I=NI,NE)
   36 NE=NI+NVE
      XVINJ(NE)=2.*ABS(XULAST)
      NVE=NVI+2
      NVI=1
C
      READ (5,4) VELA,TAN,FRAC
C
      DY=PE-PI
      Y(1)=0.0
      Y(NP3)=1.0
      DO 55 I=1,NP3
   55 Y(I)=Y(I)*DY
C
      DO 600 I=1,NP3
      U(I)=TAB(Y(I),YIN,UIN,NIN)
      F(JFU,I)=TAB(Y(I),YIN,PFUIN,NIN)
```

```
      F(JFUOX,I)=TAB(Y(I),YIN,RFUOXIN,NTN)
      F(JCO,I)=TAB(Y(I),YIN,RCOIN,NTN)
      F(JVT,I)=TAB(Y(I),YIN,VTIN,NTN)
      FS(JT,I)=TAB(Y(I),YIN,TIN,NTN)
      IF (KREAD.EQ.0) GO TO 400
      F(JK,I)=TAB(Y(I),YIN,TKIN,NTN)
      F(JD,I)=CD*F(JK,I)**1.5/(TAB(Y(I),YIN,TLIN,NTN)+1.E-20)
  400 CONTINUE
C
      DO 410 I=1,NP3
      DPDY(I)=0.0
      FS(JRY,I)=SIGMA*FS(JT,I)**4
      R(I)=RI+Y(I)*CSALFA
      FUB=F(JFUOX,I)-F(JFU,I)
      F(JOX,I)=RATIO1*F(JFU,I)+RATIO3*F(JCO,I)+RATIO2-(RATIO2+RATIO1)
     1   *F(JFUOX,I)
      F(JOX,I)=AMAX1(F(JOX,I),0.)
      F(JCO2,I)=WCO2*CX*FUB/WFU-WCO2*F(JCO,I)/WCO
      F(JH2O,I)=HY*WH2O*FUB/WFU/2.
      F(JOH,I)=0.
      F(JH2,I)=0.
      F(JO,I)=0.
      F(JOH,I)=0.
      F(JHS,I)=0.
      F(JNO,I)=0.
      F(JN,I)=0.
      FS(JN2,I)=1.0
      DO 412 JJ=1,NSPM
      J=JLOC(JJ)
  412 FS(JN2,I)=FS(JN2,I)-F(J,I)
      HPI=0.
      DO 411 JJ=1,NSPM
      J=JLOC(JJ)
  411 HPI=HPI+F(J,I)*HDR(FS(JT,I),JJ)
      F(JH,I)=HPI+FS(JN2,I)*HDR(FS(JT,I),12)+.5*U(I)*U(I)
      IF (KREAD.EQ.1) GO TO 410
      F(JK,I)=AKFAC*U(I)*U(I)
      ALM=ALFAC*(Y(NP3)-Y(I))
      IF (IOUT.NE.0) ALM=AMIN1(ALM,ALFAC*Y(I))
      ALM=AMAX1(ALM,ALFAC*Y(NP3)/100.)
      F(JD,I)=CD*F(JK,I)**1.5/ALM
  410 CONTINUE
      ALM=ALFAC*Y(NP3)
C
      DO 52 I=1,NP3
      P(I)=PRESS
      PSURL(I)=0.
      RII=R(I)
      IF (I.EQ.2) RII=.75*R(2)+.25*R(3)
      IF (I.EQ.NP2) RII=.75*R(NP2)+.25*R(NP1)
      F(JVT,I)=RII*F(JVT,I)
      VMIX=0.
      DO 413 JJ=1,NSPM
      J=JLOC(JJ)
  413 VMIX=VMIX+F(J,I)/W(JJ)
      VMIX=VMIX+FS(JN2,I)/W(12)
      RHO(I)=PRESS/FS(JT,I)/GASCON/VMIX
      IF (I.EQ.1) GO TO 52
      AFLO=.5*(R(I)**2-R(I-1)**2)
      IF (KRAD.EQ.0) AFLO=Y(I)-Y(I-1)
      OM(I)=.5*(RHO(I)*U(I)+RHO(I-1)*U(I-1))*AFLO
   52 CONTINUE
      DO 53 I=2,NP3
   53 OM(I)=OM(I-1)+OM(I)
      FLOTOT=OM(NP3)
      DO 51 I=1,NP3
   51 OM(I)=OM(I)/FLOTOT
C
      VMIX=F2A/WFU+(1.-F2A)*.03469
      ROA=PRESS/TA/GASCON/VMIX
      FLOA=ROA*UA*.5*(RB**2-RA**2)
      PSII=FLOA
      PEI=FLOTOT
      PSIE=PSII+PEI
      DYOLD=0.0
C
C     ---------------------------------------------------------------
```

```
CHAPTER6666666666666666666666666665555555  THERMODYNAMIC PROPERTIES  666666
C  *********************  START OF MAIN LOOP  *********************
   60 CONTINUE
C
C     ---------------------------------------------------------- TEST 1
      IF(ITEST) 602,601,602
  602 LAB(1)=6HTEST 1
      LAB(2)=6H
      WRITE(6,100) LAB,P(1),PRESS,DK,PSII,PSIF,PFI,FPA,ULIM,PEILIM,AFAC,
     1             AEXDLP
      LAB(1)=1HU
      LAB(2)=6H
      WRITE(6,100) LAB,(U(I),I=1,NP3)
      LAB(1)=6HF(1,I)
      LAB(2)=6H
      WRITE(6,100) LAB,(F(1,I),I=1,NP3)
      LAB(1)=6HF(2,I)
      LAB(2)=6H
      WRITE(6,100) LAB,(F(2,I),I=1,NP3)
      LAB(1)=6HF(3,I)
      LAB(2)=6H
      WRITE(6,100) LAB,(F(3,I),I=1,NP3)
      LAB(1)=6HF(4,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(4,I),I=1,NP3)
      LAB(1)=6HF(5,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(5,I),I=1,NP3)
      LAB(1)=6HF(6,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(6,I),I=1,NP3)
      LAB(1)=6HF(7,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(7,I),I=1,NP3)
      LAB(1)=6HF(8,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(8,I),I=1,NP3)
      LAB(1)=6HF(9,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(9,I),I=1,NP3)
      LAB(1)=6HF(10,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(10,I),I=1,NP3)
      LAB(1)=6H   11,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(11,I),I=1,NP3)
      LAB(1)=6HF(12,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(12,I),I=1,NP3)
      LAB(1)=6HF(13,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(13,I),I=1,NP3)
      LAB(1)=6HF(14,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(14,I),I=1,NP3)
      LAB(1)=6HF(15,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(15,I),I=1,NP3)
      LAB(1)=6HF(16,I
      LAB(2)=2H)
      WRITE (6,100) LAB,(F(16,I),I=1,NP3)
  601 CONTINUE
C
      DO 200 I=1,NP3
  200 P(I)=P(I)+DPDX(I)*DXOLD
      IF(MASSTR.NE.0) GO TO 64
      DO 65 I=1,NP3
      CPI=RATIC2*CPDR(FS(JT,I),4)+(1.-RATIC2)*CPDR(FS(JT,I),12)
      HPI=RATIO2*HDR(FS(JT,I),4)+(1.-RATIO2)*HDR(FS(JT,I),12)
      FS(JT,I)=AMAX1(1.,FS(JT,I)+(F(JH,I)-.5*U(I)*U(I)-HPI)/CPI)
   65 RHO(I)=P(I)*WMIX/FS(JT,I)/GASCON
      GO TO 66
   64 DO 61 I=1,NP3
      FUB=F(JFUOX,I)-F(JFU,I)
      F(JOX,I)=RATIO1*F(JFU,I)+RATIO3*F(JCO,I)+RATIO2-(RATIC2+RATIO1)
     1  *F(JFUOX,I)
      F(JOX,I)=AMAX1(F(JOX,I),0.)
```

```
      F(JCO2,I)=WCO2*CX*FUB/WFB-WCO2*F(JCO,I)/WCO
      F(JH2O,I)=HY*WH2O*FUB/WFU/2.
      FS(JN2,I)=1.
      DO 607 JJ=1,NSPM
      J=JLOC(JJ)
  607 FS(JN2,I)=FS(JN2,I)-F(J,I)
      HPI=0.
      CPI=0.
      DO 606 JJ=1,NSPM
      J=JLOC(JJ)
      HPI=HPI+F(J,I)*HOR(FS(JT,I),JJ)
  606 CPI=CPI+F(J,I)*CPOR(FS(JT,I),JJ)
      HPI=HPI+FS(JN2,I)*HOR(FS(JT,I),12)
      CPI=CPI+FS(JN2,I)*CPOR(FS(JT,I),12)
      FS(JT,I)=FS(JT,I)+(F(JH,I)-.5*U(I)*U(I)-HPI)/CPI
      FS(JT,I)=AMAX1(FS(JT,I),100.)
      VMIX=0.
      DO 605 JJ=1,NSPM
      J=JLOC(JJ)
  605 VMIX=VMIX+F(J,I)/W(JJ)
      VMIX=VMIX+FS(JN2,I)/WN2
   61 RHO(I)=P(I)/FS(JT,I)/VMIX/GASCON
   66 CONTINUE
      RHO(2)=RHO(1)
      RHO(NP2)=RHO(NP3)
C     ------------------------------------------------------------ TEST 2
      IF(ITEST) 604,603,604
  604 LAB(1)=6HTEST 2
      LAB(2)=4H
      WRITE(6,100) LAB,PRESS,DX,RPDDX,RDGSCW
      LAB(1)=6HFS(1,I
      LAB(2)=1H)
      WRITE(6,100) LAB,(FS(1,I),I=1,NP3)
      LAB(1)=6HFS(2,I
      LAB(2)=1H)
      WRITE(6,100) LAB,(FS(2,I),I=1,NP3)
      LAB(1)=6HRHO(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(RHO(I),I=1,NP3)
  603 CONTINUE
C     ------------------------------------------------ ADJUST R(I)
      IF (KIN.EQ.3) GO TO 609
      R(1)=TAB(XU,XR,ARI,NRP)
      IF (XU.LE.XUINJ(NUI)) GO TO 617
      R(1)=SQRT(R(1)**2+2.*(AUINJ(NUI)-STRD)/RJINJ(NUI))
  617 IF (IEND.GE.ISTEP.OR.KPAS.EQ.0) GO TO 509
      R(1)=SQRT(RA**2+2.*PSII/RHO(1)/U(1))
C
C     ------------STRIDE1------------STRIDE1------------STRIDE1---------STRIDE1
  609 CALL STRIDE(1)
C
C     ---------------------------------------------------------------------------
CHAPTER777777777777777777777777777777777777777777  FORWARD STEP  777777777
      DXOLD=AMAX1(.005*FRA*Y(NP3),DX)
      DX=FRA*Y(NP3)
      IDXFIX=0
      IF(ISTEP.LT.50) DX=.1*DX
      DX=AMIN1(DX,3.*DXOLD)
C
      IF(ISTEP.GE.IEND) GO TO 70
      IF(DX.LT.XEND-XU) GO TO 70
      DX=XEND-XU
      IDXFIX=1
      IEND=ISTEP+1
   70 IF(ISTEP.GE.IOUT) GO TO 71
      IF(DX.LT.XOUT-XU) GO TO 71
      DX=XOUT-XU
      IDXFIX=1
      IOUT=ISTEP+1
   71 IF (DX.LT.XULAST-XU) GO TO 72
      DX=XULAST-XU
      IDXFIX=1
   72 IF( DX.GT.0.) GO TO 73
      IFIN=1
      GO TO 1011
C
   73 XD=XU+DX
```

```
C     ----- FURTHER ADJUSTMENTS TO BY ARE MADE IN CHAPTERS 8 AND 9.
C
C     ------------------------------------------------------------------
CHAPTER8888888888888888888888888888  ADJUST LONGITUDINAL CONDITIONS  8888888
C
C     CHAPTER8A ------------------------------------BOUNDARY CONDITIONS
C     ---------------- I BOUNDARY
      IF(ISTEP-IAX) 8000,80,84
 8000 IF(ISTEP-IEND) 8002,83,84
C     ---------------------------- WALL
 8002 KIN=1
      U(1)=0.
      RMI=0.
      IF(ISTEP.EQ.0) TAUI=0.
      EWALL=9.
      DO 81 JJ=1,NSPM
      J=JLOC(JJ)
      INDI(J)=2
   81 AJI(J)=0.
      INDI(JFUDX)=2
      AJI(JFUDX)=0.
      INDI(JM)=2
      AJI(JM)=0.
      DO 74 J=13,15
      INDI(J)=1
   74 F(J,1)=0.0
      IF (IFLUX.EQ.0) GO TO 84
      FS(JT,1)=TWALL
      INDI(JM)=1
      HPI=0.
      DO 76 JJ=1,NSPM
      J=JLOC(JJ)
   76 HPI=HPI+F(J,1)*HDR(TWALL,JJ)
      F(JM,1)=HPI+FS(JM2,1)*HDR(TWALL,12)
      GO TO 84
C     -------------------- FREE
   83 KIN=2
      TAUI=0.
      U(1)=UA
      RMI=0.
      RU(1)=RHO(1)*U(1)
      F(JM,1)=F1A
      F(JFU,1)=F2A
      F(JFUDX,1)=F2A
      DO 181 JJ=2,NSPM
      J=JLOC(JJ)
  181 F(J,1)=0.
      F(JOX,1)=RATIC2*(1.-F2A)
      F(JVT,1)=R(1)*VTA
      F(JK,1)=AKFAC*UA*UA
      F(JD,1)=CD*F(JK,1)**1.5/ALM
      GO TO 84
C     ------------------ SYMMETRY AXIS
   80 KIN=3
      RMI=0.
      R(1)=RA
      PSII=0.
      TAUI=0.
C     --------------------------AXIAL INJECTION
   84 RI=TAB(XD,XR,ARI,KRP)
      IF (XD.LE.XUINJ(NUI)) GO TO 392
      IF (ABS(AUINJ(NUI)-SUM1).GT.1.E-10) GO TO 390
      NUI=NUI+1
      SUM1=0.
      GO TO 392
  390 KIN=2
      TAUI=0.
      ARG=2.*ABS(SUM1/AUINJ(NUI)-.5)
      U(1)=UINJ(NUI)*(1.-ARG**(N1/UPAT
      T=TUINJ(NUI)
      F(JM,1)=RATIC2*HDR(T,4)+(1.-RATIO2)*HDR(T,12)
      DO 387 JJ=1,NSPM
      J=JLOC(JJ)
  387 F(J,1)=0.
      F(JFUDX,1)=0.
      F(JOX,1)=RATIC2
      F(JVT,1)=R(1)*VTUINJ(NUI)
```

```
      VECZ=UINJ(NUI)**2+VTUINJ(NUI)**2
      F(JK,1)=AKFAC*VECZ
      F(JD,1)=CD*F(JK,1)**1.5/ALM
      FS(JT,1)=TUINJ(NUI)
      RHO(1)=PDGSCN/FS(JT,1)
      RU(1)=RHO(1)*U(1)
      RI=SQRT(RI**2+2.*(AUINJ(NUI)-SUM1)/RUINJ(NUI))
  382 CONTINUE
C     ---------------------------------RADIAL INJECTION
      IF (XD.LE.XVINJ(NVI)) GO TO 394
      IF (ABS(AVINJ(NVI)-SUM3).GT.1.E-10) GO TO 390
      NVI=NVI+1
      SUM3=0.
      GO TO 394
  390 IF (KIN.NE.2) GO TO 392
      PSII=PSII-(AUINJ(NVI)-SUM1)
      SUM1=AUINJ(NUI)
      FIN=1
      RI=TAB(XD,XR,ARI,NBP)
  392 U(1)=UVINJ(NVI)
      T=TVINJ(NVI)
      F(JM,1)=RATIO2*HOR(T,4)+(1.-RATIO2)*HOR(T,12)
      DO 388 JJ=1,NSPM
      J=JLOC(JJ)
  388 F(J,1)=0.
      F(JFUOX,1)=0.
      F(JOX,1)=RATIO2
      F(JVT,1)=R(1)*VTVINJ(NVI)
      VEC2=UVINJ(NVI)**2+VINJ(NVI)**2+VTVINJ(NVI)**2
      F(JK,1)=AKFAC*VEC2
      F(JD,1)=CD*F(JK,1)**1.5/ALM
      DO 207 J=1,NF
  207 INOI(J)=1
      FS(JT,1)=TVINJ(NVI)
      RHO(1)=PDGSCN/FS(JT,1)
      RMI=R(1)*RHO(1)*VINJ(NVI)
      IF (ABS(RMI)*DX.LT.AVINJ(NVI)-SUM3) GO TO 394
      PMI=(AVINJ(NVI)-SUM4)/DY
  394 CONTINUE
C     -------------------- E BOUNDARY
      IF (ISTEP-IOUT) 8004,85,85
C     ------------------------ WALL
 8004 KEX=1
      U(NP3)=0.
      PME=0.
      IF(ISTEP.EQ.0) TAUE=0.
      EWALL=0.
      DO 82 JJ=1,NSPM
      J=JLOC(JJ)
      INDE(J)=2
   82 AJE(J)=0.
      INDE(JM)=2
      AJE(JM)=0.
      INDE(JFUOX)=2
      AJE(JFUOX)=0.
      DO 75 J=13,15
      INDE(J)=1
   75 F(J,NP3)=0.0
      IF (IFLUX.EQ.0) GO TO 86
      INDE(JH)=1
      FS(JT,NP3)=TWALL
      HPI=0.
      DO 77 JJ=1,NSPM
      J=JLOC(JJ)
   77 HPI=HPI+F(J,NP3)*HOR(TWALL,JJ)
      F(JH,NP3)=HPI+FS(JM2,NP3)*HOR(TWALL,12)
      GO TO 86
C     ------------------------------------------FREE
   85 KEX=2
      TAUE=0.
      U(NP3)=UD
      RU(NP3)=RHO(NP3)*U(NP3)
      DO 158 JJ=1,NSPM
      J=JLOC(JJ)
  158 F(J,NP3)=0.
      F(JOX,NP3)=RATIO2*(1.-F20)
      F(JM,NP3)=F10
```

```
      F(JFU,NP3)=F2D
      F(JFUOX,NP3)=F2D
      F(JVT,NP3)=R(NP3)*VTD
      F(JK,NP3)=AKFAC*UD*UD
      F(JD,NP3)=CD*F(JK,NP3)**1.5/ALM
C     ----------------------------AXIAL INJECTION
   86 RE=TAB(XD,XR,ARE,NRP)
      IF (XD.LE.XUINJ(NUE)) GO TO 372
      IF (ABS(AUINJ(NUE)-SUM2).GT.1.E-10) GO TO 369
      NUE=NUE+1
      SUM2=0.
      GO TO 372
369   KEX=2
      TAUE=0.
      ARG=2.*ABS(SUM2/AUINJ(NUE)-.5)
      U(NP3)=UINJ(NUE)*(1.-ARG**SLM)/NRAT
      T=TUINJ(NUE)
      F(JH,NP3)=RATIO2*HDR(T,4)+(1.-RATIO2)*HDR(T,12)
      DO 371 JJ=1,NSPR
      J=JLOC(JJ)
  371 F(J,NP3)=0.
      F(JFUOX,NP3)=0.
      F(JOX,NP3)=RATIO2
      F(JVT,NP3)=R(NP3)*VTUINJ(NUE)
      VEC2=UINJ(NUE)**2+VTUINJ(NUE)**2
      F(JK,NP3)=AKFAC*VEC2
      F(JD,NP3)=CD*F(JK,NP3)**1.5/ALM
      FS(JT,NP3)=TUINJ(NUE)
      RHO(NP3)=PDGSCN/FS(JT,NP3)
      RU(NP3)=U(NP3)*RHO(NP3)
      RE=SQRT(RE**2-2.*(AUINJ(NUE)-SUM2)/RUINJ(NUE))
  372 CONTINUE
C     ----------------------------RADIAL INJECTION
      IF (XD.LE.XVINJ(NVE)) GO TO 202
      IF (ABS(AVINJ(NVE)-SUM4).GT.1.E-10) GO TO 205
      SUM4=0.
      NVE=NVE+1
      GO TO 202
206   IF (KEX.NE.2) GO TO 209
      PSIE=PSIE+(AUINJ(NUE)-SUM2)
      SUM2=AUINJ(NUE)
      KEX=1
      RE=TAB(XD,XP,ARE,NRP)
  209 U(NP3)=UVINJ(NVE)
      T=TVINJ(NVE)
      F(JH,NP3)=RATIO2*HDR(T,4)+(1.-RATIO2)*HDR(T,12)
      DO 389 JJ=1,NSPF
      J=JLOC(JJ)
  389 F(J,NP3)=0.
      F(JFUOX,NP3)=0.
      F(JOX,NP3)=RATIO2
      F(JVT,NP3)=R(NP3)*VTVINJ(NVE)
      VEC2=UVINJ(NVE)**2+VINJ(NVE)**2+VTVINJ(NVE)**2
      F(JK,NP3)=AKFAC*VEC2
      F(JD,NP3)=CD*F(JK,NP3)**1.5/ALM
      DO 208 J=1,NF
208   INDE(J)=1
      FS(JT,NP3)=TVINJ(NVE)
      RHO(NP3)=PDGSCN/FS(JT,NP3)
      RVE=R(NP3)*RHO(NP3)*VINJ(NVE)
      IF (ABS(RME)*DX.LT.AVINJ(NVE)-SUM4) GO TO 202
      RME=-(AVINJ(NVE)-SUM4)/DX
  202 CONTINUE
C     -------------- CALCULATE WALL TEMPERATURE
C
      IF (IFLUX.EQ.0) GO TO 79
      IF (IEND.GT.ISTEP) CALL WTEMP (1)
      IF (IOUT.GT.ISTEP) CALL WTEMP (NP3)
C     ---------- STRAD ---------- STRAD ---------- STRAD ----------
      CALL STRAD
C     ---------------------------------------------------------------
   79 CONTINUE
C
C
C     CHAPTER 3R ------------------------------------- DUCT GEOMETRY
      IF (ISTEP.GE.IOUT) GO TO 80
      IF(ISTEP.GT.3) GO TO 87
```

```
      ROUT=RO
      ADUD=(R(NP3)**2-R(1)**2)*.5
      IF (KRAD.EQ.0) ADUD=Y(NP3)-Y(1)
   87 ADUU=ADUD
      AIN=.5*R(1)**2
      IF (ISTEP.EQ.IOUT) ADUU=.5*ROUT**2
      AFLU=R(NP3)**2*.5-AIN
      IF (KRAD.EQ.0) AFLU=Y(NP3)-Y(1)
      AEX=AFLU-ADUU
      AEXD=AEX/AFLU
      IF (IDIFIX.EQ.1) GO TO 88
      IF(ABS(AEXD).GT.AEXDLM) DX=DX*AEXDLM/ABS(AEXD)
      XD=XU+DX
   88 ADUD=.5*(RE**2-RI**2)
      IF (KRAD.EQ.0) ADUD=RE-RI
      DA=AFAC*(ADUD-AFLU)
C
C     CHAPTER 9C ------------------------ SUBSONIC PRESSURE GRADIENT
C     -----------------------------UBAR
   89 UBAR=0.
      DO 820 I=2,NP2
  820 UBAR=UBAR+(U(I)+U(I+1))*DPSI(I)
      UBAR=.5*UBAR
      IF(KIN.EQ.2) UBAR=(UBAR-UA)*PEI/PSIE+UA
C     ---------------------------SUBSONIC FLOW
  803 IF (ISTEP-IOUT) 822,823,823
  823 DPODX=0.
      GO TO 824
C     ----------------------------------- CONFINED SUBSONIC FLOW
  822 GO TO (830,835), IDFDX
  835 IF (ISTEP.EQ.0.OR.KIN.EQ.2) GO TO 830
C     --------------- GRID FILLING DUCT VERSION -----------
      ROUBAR=PEI/ADUU
      RCBAR=ROUBAR/UBAR
      DUDP=-1./(ROUBAR+(TAUE**(NP3)-TAUI**(1))*DX/ADUU/UBAR)
      UDRODP=ROUBAR/GAMMA/P(NP3)
      DPDU=ROUBAR*(AFLU/ADUU-1.)
      DPC=DPDU/(ROBAR*DUDP+UDRODP)
      UFAC=DPC*DUDP/UBAR+1.
C     ------- ADJUST VELOCITY PRESSURE AND DENSITY PROFILES --------
      DO 940 I=1,NP3
      U(I)=U(I)*UFAC
      P(I)=P(I)+DPC
  940 RHO(I)=RHO(I)*(1.+GAMMA*DPC/P(I))
      DP=DP+DPC
      DPODX=DP/DXOLD
C     -------- RECALCULATE DISTANCES ----------
      CALL STRIDE(1)
      GO TO 824
C     ------------- STANDARD GENMIX VERSION ---------
  830 FLOTOT=PSIE-PSII*FLOAT(1)/KIN
      DYNHED=UBAR*FLOTOT/AFLU
      DPODX=(DYNHED*DA/DX-TAUI**(1)-TAUE**(NP3)+2.*UBAR*(RPE-RPI))/ADUD
      DP=DPODX*DX
  824 CONTINUE
C     --------- 2*FLOW AREAS ------------
      DO 307 I=2,NP2
  307 RDY(I)=PEI*(DP(I+1)-DP(I-1))/RHO(I)/U(I)
      GO TO (310,312,312), KIN
  310 RDY(2)=(R(1)+.5*(R(2)+R(3)))*YI
      GO TO 313
  312 RDY(2)=PEI*OM(3)/RHO(3)/U(3)
  313 GO TO (314,315,315), KEX
  314 RDY(NP2)=(R(NP3)+.5*(R(NP2)+R(NP1)))*YE
      GO TO 316
  315 RDY(NP2)=PEI*(1.-OM(NP1))/RHO(NP1)/U(NP1)
  316 CONTINUE
      RDY(1)=0.0
      RDY(NP3)=0.0
      IF (ISWRL.EQ.0) GO TO 227
C     -------- PRESSURE GRADIENT W/SWIRL EFFECTS INCLUDED ----------
      VOR2=(F(JVT,NP2)/(.75*R(NP2)+.25*R(NP1))**2)**2
      RALFA=0.5*PEI*CSALFA
      PD=0.
      DPDX(NP2)=0.0
      DO 225 JI=3,NP2
      I=NP3-JI+I
```

```
      VOR2P1=VOR2
      RII=R(I)
      IF (I.EQ.2) RII=.75*R(2)+.25*R(3)
      VOR2=(F(JVT,I)/RII**2)**2
      PD=PD-PALFA*(VOR2/U(I)+VOR2P1/U(I+1))*RHO(I)
      IF (ISTEP.GT.0) GO TO 224
      PSWRL(I)=PD
      P(I)=P(I)+PD
      IF (I.EQ.2) P(1)=P(2)
  224 DPDX(I)=(PD-PSWRL(I))/DXOLD
  225 PSWRL(I)=PD
      IF (KEX.EQ.2) GO TO 260
      DPDXDA=0.0
      SRDY=0.0
      DO 250 I=2,NP2
      SRDY=SRDY+RDY(I)
250   DPDXDA=DPDXDA+DPDX(I)*DXOLD*RDY(I)
      DP=DP-DPDXDA/SRDY
      DO 255 I=2,NP2
  255 DPDX(I)=DPDX(I)+DP/DXOLD
  260 CONTINUE
      DPDX(1)=DPDX(2)
      DPDX(NP3)=DPDX(NP2)
      GO TO 242
C ---------      PRESSURE GRADIENT FOR NON-SWIRLING FLOW      ------------
  227 DO 825 I=1,NP3
  825 DPDX(I)=DPDOX
C     ------------------------------------------------------------ TEST 3
  242 IF (ITEST) 802,801,802
  802 LAB(1)=6HTEST 3
      LAB(2)=6H
      WRITE(6,100) LAB,UPAR,DYNHFD,DY,DA,DPDOX,CEXD,RMI
      WRITE(6,101) LAB,ISTEP,XTN,XEX,TAX,TEND,TOUT
      LAB(1)=4HY(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(Y(I),I=1,NP3)
      LAB(1)=4HR(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(R(I),I=1,NP3)
      LAB(1)=5HRU(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(RU(I),I=1,NP3)
      LAB(1)=6HDPDX(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(DPDX(I),I=1,NP3)
      LAB(1)=6HPSWRL(
      LAB(2)=6HI)
      WRITE (6,100) LAB,(PSWRL(I),I=1,NP3)
  801 CONTINUE
C
C ----------------------------------------------------------------------
CHAPTER9999999999999999999999  TRANSPORT AND ENTRAINMENT PROPERTIES  9999
C -----  LAMINAR VISCOSITY ASSUMED TO BE THAT OF AIR  -----------------
 900  CONTINUE
      DO 98 I=1,NP3
      EMU(I)=VISCO(FS(JT,I))
   98 CONTINUE
      EMU(2)=EMU(1)
      EMU(NP2)=EMU(NP3)
C     ------------------------------------------------------------ TEST 4
      IF(ITEST) 902,901,902
  902 LAB(1)=6HTEST 4
      LAB(2)=6H
      WRITE(6,100) LAB,RMI,EMF,PFI
      LAB(1)=6HEMU(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(EMU(I),I=1,NP3)
  901 CONTINUE
C
C     -----------AUX-----------AUX-----------AUX-----------AUX-----------AUX
      CALL AUX2(0)
C     ------------------------------ ENTRAINMENT CONTROL.
      IF(KIN.NE.2) GO TO 94
      RAT=ABS((U(3)-U(1))/(U(NP3)-U(1)+1.E-30))
      IF(RAT.LT.ULIM) EM U(2)=EM U(2)*RAT/ULIM
      RMI=2.*EM U(2)
   94 CONTINUE
```

```
      IF(NEX.NE.2) GO TO 97
      RAT=ABS((U(NP1)-U(NP3))/(U(NP3)-U(1)+1.E-30))
      RME=-2.*EM U(NP1)
      IF(RAT.LT.ULIM) RME=RME*(RAT/ULIM)**2
   97 IF (IDXFIX.EQ.1) GO TO 96
C     ---------- LIMIT ON INCREMENT IN PEI.
      IF((ABS(RMI)+ABS(RME))*DX.LT.PEI*PEILIM) GO TO 96
      DX=PEI*PEILIM/(ABS(RMI)+ABS(RME))
      XD=XU+DX
   96 CONTINUE
      IF (XD.LE.XUINJ(NUI)) GO TO 91
      IF (ABS(RMI)*DX.LT.AUINJ(NUI)-SUM1) GO TO 91
      RMI=(AUINJ(NUI)-SUM1)/DX
   91 IF (XD.LE.XUINJ(NUE)) GO TO 92
      IF (ABS(RME)*DX.LT.AUINJ(NUE)-SUM2) GO TO 92
      RME=-(AUINJ(NUE)-SUM2)/DX
   92 CONTINUE
C     ---------- ADJUSTMENT OF DX TO REACH AXIS.
      IF (IEND.GT.ISTEP) GO TO 95
      IF(ISTEP.GE.IAX) GO TO 95
      IF(PSII.GT.RMI*DX.OR.IAX.EQ.ISTEP+1) GO TO 95
      RMI=PSII/DX
      IAX=ISTEP+1
C
C ----------DROP------------DROP----------------DROP--------------------
   95 CALL DROP
C ----------------------------------------------------------------------
C     -----------STRIDE2-----------STRIDE2-----------STRIDE2--------STRIDE2
      CALL STRIDE(2)
C
C ----------------------------------------------------------------------
CHAPTER 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10   OUTPUT   10 10 10
 1000 IF(ISTEP.GT.3) GO TO 106
      WRITE (6,9000)
 9000 FORMAT (1H1)
CHAPTER 104 ---------------------------------------   HEADINGS
C
      WRITE (6,1013) TITLE,MCOF2,IOPDX,MODEL,MASSTR,INERT,KRAD,IFLUX
 1013 FORMAT (1H1,22A6/12 5/7H MODER=,I3,7H IOPDX=,I3,7H MODEL=,I3,
     1 8H MASSTR=,I3,7H INERT=,I3,6H KRAD=,I3,7H IFLUX=,I3)
C
      WRITE (6,1010) UA,UD,TA,TD,RA,RB,RD,XEND,XOUT,XULAST,PRESS,
     1 PRESP1,ARCOM1,CP1,VTA,VTD
 1010 FORMAT (1H ,1X,2HUA,8X,2HUD,9X,2HTA,9X,2HTD,9X,2HRA,9X,2HRB,8X,
     1 2HRD,8X,4HXEND,6X,4HXOUT,6X,6HXULAST/1H ,1P10E10.3/1H ,
     2 6H PRESS,5X,6HPRESP1,4X,6HARCOM1,4X,3HCP1,7X,3HVTA,7X,3HVTD/1X,
     2 1P10E10.3)
C
      LAB(1)=5HOMEGA
      LAB(2)=6H
      WRITE(6,100) (AB,(OM(I)),I=1,NP3)
      PRESS1=PRESS
      MINJ=12
      IF (XUINJ(NUI).GT.XULAST.AND.XUINJ(NUE).GT.XULAST) GO TO 1200
      WRITE (6,1205)
 1205 FORMAT (/6X,'AXIAL INJECTION'/6X,15(1H*)//6X,'SLOT',4X,
     1 'BOUNDRY',10X,'X',9X,'YL',10X,'U',9X,'VT',7X,'TEMP',7X,'PDOT',
     2 10X,'M',9X,'AP'/10(3X,8(1H*)))
      INDX=0
      IPT=0
      DO 1210 II=1,MINJ
      IF (INDX.EQ.2) GO TO 1210
      IF (XUINJ(II).GT.XULAST) INDX=INDX+1
      IF (XUINJ(II).GT.XULAST) GO TO 1210
      IB=1HI
      IF (II.GE.NUE) IB=1HE
      IPT=IPT+1
      WRITE (6,1215) IPT,IB,XUINJ(II),XLUINJ(II),UINJ(II),VTVINJ(II),
     1 TUINJ(II),AUINJ(II),MUINJ(II),APUINJ(II)
 1215 FORMAT (7X,I2,9X,A1,3X,8(1PE11.3))
 1210 CONTINUE
 1200 IF (XVINJ(NVI).GT.XULAST.AND.XVINJ(NVE).GT.XULAST) GO TO 1223
      WRITE (6,1225)
 1225 FORMAT (//6X,'RADIAL INJECTION'/6X,16(1H*)//6X,'SLOT',4X,
     1 'BOUNDRY',10X,'X',10X,'V',9X,'VT',7X,'TEMP',7X,'MDOT'/
     2 8(3X,8(1H*)))
      INDX=0
```

```
      IPT=0
      DO 1230 II=1,NINJ
      IF (INDX.EQ.2) GO TO 1230
      IF (XVINJ(II).GT.XULAST) INDX=INDX+1
      IF (XVINJ(II).GT.XULAST) GO TO 1230
      IB=1HI
      IF (II.GE.NVE) IB=1HE
      IPT=IPT+1
      WRITE (6,1215) IPT,IB,XVINJ(II),VINJ(II),VTVINJ(II),TVINJ(II),
     1 AVINJ(II)
 1230 CONTINUE
 1220 IF (IFLUX.EQ.0) GO TO 1247
      WRITE (6,1235)
 1235 FORMAT (/3X,*BOUNDRY*,7X,*VELA*,8X,*TAN*,7X,*PRAD*/4(3X,*(I-O)))
      IB=1HI
      DO 1240 II=1,2
      WRITE (6,1245) IB,VELA(II),TAN(II),PRAD(II)
 1245 FORMAT (7X,A1,3X,3(1PE11.3))
      IB=1HE
 1240 CONTINUE
 1247 CONTINUE
  106 CONTINUE
C     -------------------------------------------------- TEST 5
      IF(ITEST) 1002,1001,1002
 1002 LAB(1)=6HTEST 5
      LAB(2)=6H
      WRITE(6,100) LAB,RMI,RME,DX
 1001 CONTINUE
C
CHAPTER 108 ---------------------------------------- TESTS FOR PRINTOUT
C     ----- IPRINT=0 GIVES NO OUTPUT,  =1 GIVES SINGLE VARIABLES ONLY,
C                  =2 GIVES BOTH SINGLE AND ARRAY (PROFILE) VARIABLES.
 1011 IPRINT=0
      IF (MOD(ISTEP,NSTAT).EQ.0) IPRINT=1
      IF (MOD(ISTEP,NPROF).EQ.0) IPRINT=2
      IF(ISTEP.EQ.IEND.OR.ISTEP.EQ.IAX.OR.ISTEP.EQ.IOUT) IPRINT=2
      IF(ITEST.NE.0.OR.IFIN.NE.0) IPRINT=2
      IF (MOD(ISTEP,NPLOT).EQ.0.AND.ISTEP.GT.0) IPRINT=3
C     ----- THE NEXT STATEMENT PROVIDES A PLOT JUST PRIOR TO TERMINATION
      IF(XU.GE.XULAST.OR.IFIN.NE.0.OR.ISTEP.EQ.LASTEP) IPRINT=3
C
CHAPTER 10C --------------------------SINGLE STATION VARIABLES.
      IF(IPRINT.EQ.0) GO TO 110
      PRESSD=P(NP3)/PRESS1-1.
      WRITE (6,1030) ISTEP,IAX,IEND,IOUT,KIN,KEX,DX,PSII,PSIE,RMI,RME,
     1  PEI,PRESSD,AERO
 1030 FORMAT(7H0ISTEP=,I5,5H IAX=,I5,6H IEND=,I5,6H IOUT=,I5,5H KIN=,I2,
     1 5H KEX=,I2,4H DX=,1PE11.3,6H PSII=,E11.3,6H PSIE=,E11.3/
     2 5H RMI=,E11.3,5H RME=,E11.3,5H PEI=,E11.3,8H PRESSD=,E11.3,
     3 6H AERO=,E11.3)
C
C
      UBAR=0.
      DO 1020 J=1,NF
      AJID(J)=0.0
      AJED(J)=0.0
 1020 FLUX(J)=0.
      PFLUX=0.0
      DO 1021 I=2,NPI
      UBAR=UBAR+DM3(I)*(U(I)+U(I+1))
      PFLUX=PFLUX+PSWPL(I)*PDY(I)
      DO 1021 J=1,NF
      FLUX(J)=FLUX(J)+DM3(I)*(F(J,I)+F(J,I+1))
 1021 CONTINUE
      UBAR=.5*UBAR
      UFLUX=PEI*UBAR+PFLUX
      DO 1022 J=1,NF
 1022 FLUX(J)=.5*PEI*FLUX(J)
C
      UREF=UBAR
      RUREF=PEI/.5/(R(1)+R(NP3))/Y(NP3)
      DO 1023 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1023
      DFI(J)=FLUX(J)/PEI-F(J,1)
      DFE(J)=DFI(J)+F(J,1)-F(J,NP3)
 1023 CONTINUE
      JFLUX=UFLUX-PSIFE*U(NP3)+U(1)*PSII
```

```
      FLUX(JFU)=FLUX(JFU)-PSIE*F2D+F2A*PSTI
      FLUX(JH)=FLUX(JH)-PSIE*F1D+F1A*PSTI
C
      WRITE (6,1031) XU,UFLUX,(FLUX(J),J=1,NF)
 1031 FORMAT (4H XJ=,1PE11.3,7H UFLUX=,E11.3,9H FLUX(J)=,8E11.3/42X,
     1 8E11.3)
C
      IF(KIN.NE.1) GO TO 1024
      TAUID=TAUI/UREF/RUREF
      DO 1025 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1025
      AJID(J)=AJI(J)/RUREF/DFI(J)
 1025 CONTINUE
      WRITE(6,1029) KIN,TAUID,(AJID(J),J=1,NF)
 1029 FORMAT (5H KIN=,I2,7H TAUID=,1PE11.3,9H AJID(J)=,8E11.3/34X,
     1 8E11.3)
C
 1024 IF(KEX.NE.1) GO TO 1026
      TAUED=TAUE/UREF/RUREF
      DO 1027 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1027
      AJED(J)=AJE(J)/RUREF/DFE(J)
 1027 CONTINUE
      WRITE(6,1028) KEX,TAUED,(AJED(J),J=1,NF)
 1028 FORMAT (5H KEX=,I2,7H TAUED=,1PE11.3,9H AJED(J)=,8E11.3/34X,
     1 8E11.3)
 1026 CONTINUE
C
CHAPTER 100   ---------------------------PROFILES AND OTHER ARRAYS.
      IF(IPRINT.EQ.1) GO TO 110
C
      LAB(1)=6HR1,Y'S
      LAB(2)=6H
      DIV=1.
      DO 1095 I=1,NP3
 1095 OUT(I)=Y(I)/DIV
      WRITE (6,100) LAB,R(1),(OUT(I),I=2,NP2,ITHIN),Y(NP3)
      XAXIS=4HY(I)
      DO 1085 I=1,NP3
 1085 XPLOT(I)=OUT(I)
C
      LAB(1)=1HU
      LAB(2)=6H
      SUB=0.
      DIV=1.
      IF(KIN.EQ.3) DIV=U(1)+1.E-30
      DO 1094 I=1,NP3
 1094 OUT(I)=(U(I)-SUB)/DIV
      IF (NOVEL.NE.1) WRITE (6,100) LAB,U(1),(OUT(I),I=2,NP2,ITHIN),
     1 U(NP3)
      NY=1
      YAXES(1,1)=6HVELOCI
      YAXES(1,2)=2HTY
      SYMBOL(1)=1HJ
      DO 1084 I=1,NP3
 1084 YPLOT(1,I)=OUT(I)
C
      INDX=0
      DO 1050 KV=1,NF
      KVV=KV+INDX
      IF (IPRNT(KVV).EQ.0) GO TO 1050
      LAB(1)=LAB1(KVV)
      LAB(2)=LAB2(KVV)
      DO 1082 I=1,NP3
 1082 OUT(I)=F(KV,I)
      IF (KV.NE.JVT) GO TO 1075
      VTMAX=0.
      DO 1086 I=2,NP3
      DIV=R(I)
      IF (I.EQ.2) DIV=.75*R(2)+.25*R(3)
      IF (I.EQ.NP2) DIV=.75*R(NP2)+.25*R(NP1)
      OUT(I)=OUT(I)/DIV
 1086 VTMAX=AMAX1(VTMAX,OUT(I))
 1075 IF (KV.NE.JD) GO TO 1076
      DO 1077 I=1,NP3
 1077 OUT(I)=CD*F(JK,I)**1.5/(OUT(I)+1.E-20)
 1076 WRITE (6,100) LAB,F(KV,1),(OUT(I),I=2,NP2,ITHIN),F(KV,NP3)
```

```
      IF (IPLOT(KVV).EQ.0) GO TO 1090
      NY=NY+1
      YAXES(NY,1)=LAB1(KVV)
      YAXES(NY,2)=LAB2(KVV)
      SYMBOL(NY)=SYM(KVV)
      DO 1090 I=1,NP3
 1090 YPLOT(NY,I)=OUT(I)
 1080 CONTINUE
C
      INDX=NF
      DO 1180 KV=1,NFS
      KVV=KV+INDX
      IF (IPRNT(KVV).EQ.0) GO TO 1180
      LAB(1)=LAB1(KVV)
      LAB(2)=LAB2(KVV)
      DO 1182 I=1,NP3
 1182 OUT(I)=FS(KV,I)
      WRITE (6,100) LAB,FS(KV,1),(OUT(I),I=2,NP2,ITHIN),FS(KV,NP3)
      IF (IPLOT(KVV).EQ.0) GO TO 1180
      NY=NY+1
      YAXES(NY,1)=LAB1(KVV)
      YAXES(NY,2)=LAB2(KVV)
      SYMBOL(NY)=SYM(KVV)
      DO 1190 I=1,NP3
 1190 YPLOT(NY,I)=OUT(I)
 1180 CONTINUE
C
      LAB(1)=6HPRESS
      IF (ISWRL.EQ.0) GO TO 1100
      LAB(2)=6H
      SUB=P(NP3)
      DIV=1.0
      DO 1112 I=1,NP3
 1112 OUT(I)=(P(I)-SUB)/DIV
      WRITE (6,100) LAB,P(1),(OUT(I),I=2,NP2,ITHIN),P(NP3)
 1100 IF (MODEL.NE.2) GO TO 1104
      LAB(1)=6HAMU(I)
      LAB(2)=6H
      WRITE (6,100) LAB,AMU(1),(AMU(I),I=2,NP2,ITHIN),AMU(NP3)
 1104 CONTINUE
      IF(IPRINT.EQ.2) GO TO 110
      WRITE(6,1070) XU,ISTEP
 1070 FORMAT(1H ,11HPLOT AT XU=,1PE11.3,8H, ISTEP=,I5)
      DO 1071 J=1,NY
      YPLOT(J,2)=YPLOT(J,1)
 1071 YPLOT(J,NP2)=YPLOT(J,NP3)
      CALL PLOTS(XPLOT,43,NP3,XAXIS,YPLOT,10,NY,YAXES,SYMBOL)
C ---------------------------------------------------------------------
CHAPTER 11  11  11  11  11  11  11  11  11  11  11   END OF MAIN LOOP
  110 IF(ISTEP.GE.LASTEP.OR.XU.GE.XULAST.OR.IFIN.NE.0) GO TO 111
C
C         ----------STRIDE3----------STRIDE3----------STRIDE3--------STRIDE3
      CALL STRIDE(3)
      IF(IFIN) 1011,60,111
C
C     ----------------------------------------- TERMINATION
  111 WRITE(6,112) ISTEP,LASTEP,XU,XULAST,IFIN
  112 FORMAT(23H TERMINATED WITH ISTEP=,I5,8H LASTEP=,I5,
     1 4H XU=,1PE11.3,8H XULAST=,E11.3,6H IFIN=,I3)
C ---------------------------------------------------------------------
  120 CONTINUE
      STOP
  100 FORMAT (1H0,A6,A2,1P11E11.3/(9X,11E11.3))
  101 FORMAT (1H0,A6,A2,11I11)
      END
```

CARD NR.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
802	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
829	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
833	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.

```
FUNCTION TAB          73/74    OPT=0 TRACE                    FTN 4.6+439        09/24/79  13.44.16        PAGE    1

                 FUNCTION TAB (X,XX,YY,NTAB)
                 DIMENSION XX(1),YY(1)
                 IF (NTAB.GT.1) GO TO 5
                 TAB=0.0
                 RETURN
               5 F=1.
                 IF (XX(1).GT.XX(2)) F=-F
                 DO 10 J=1,NTAB
                 I=J
                 IF (F*(XX(I)-X)) 10,40,20
              10 CONTINUE
              20 IF (I.NE.1) GO TO 30
                 I=2
              30 J=I-1
                 DEL=XX(I)-XX(J)
                 IF (DEL.EQ.0.0) GO TO 50
                 TAB=(YY(I)*(X-XX(J))-YY(J)*(X-XX(I)))/DEL
                 RETURN
              40 TAB=YY(I)
                 RETURN
              50 WRITE (6,60) X,I,J
                 CALL EXIT
              60 FORMAT (* *** ERROR IN SUBROUTINE TAB ***,F15.4,2I5)
                 END

CARD NO. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM
    7       I        XX        ARRAY REFERENCE OUTSIDE DIMENSION BOUNDS.
```

```
FUNCTION VISCO      73/74    OPT=0 TRACE                    FTN 4.6+439         08/24/78  13.44.16        PAGE     1

                     FUNCTION VISCO(T)                                                 TA         26
                     IF (T.GT.667.) GO TO 10                                           TA         27
                     VISCO=1.808E-5*(T/294.4)**0.75                                    TA         28
                     RETURN                                                            TA         29
                  10 VISCO=4.464E-5*SQRT(T/1111.)                                      TA         30
                     RETURN                                                            TA         31
                     END                                                               TA         32
```

```
      SUBROUTINE AUX(NV)
      COMMON/COMA/A(43),AAE(3A),AJ(12),B(43),C(43),CSALFA,D(43),
     1 EPSI(43),DX,EMU(43),F(16,43),FS(3,43),IAX,IEND,IFIN,INDE(16),
     2 INDI(16),IOUT,ISTEP,ITEST,IUTDAP,JS,JSW,JV,JY,KEX,KIN,KRAD,N,
     3 NP2,NE,MODEL,NP1,NP2,NP3,OM(43),OMD(43),R(43),PEI,PB(16),
     4 PREF(16),PSIE,PSII,R(43),RHO(43),RU(43),RUF,RPT,SD(43),SU(43),
     5 TAUE,TAUI,U(43),XD,XU,Y(43),YE,YI,YCARL(43),RDY(43),ISOLVE(16),
     6 US(43),ARU(43),SUM1,SUM2,SUM3,SUM4,PSSCN,FDIFI(16),FDIFE(16),
     7 GE(16),GI(16),JLOC(12),M(12),J4,JFU,JC22,JC2,JDE,JH2O,JO,JC,J+S,
     8 JH2,JN,JNO,JN2,JUT,JD,JF,JT,JRV,NTS,NTSM,ASSCO,SCATR,ROM(200),
     9 EMI,SIGMA,CP,JFJCX,IFLUX,FVAP(43),TFJEL,NFET
      COMMON/COMB/AV,ALPS,EMALL,FD,4,NFU,IMESY,MASSTR,MODEL,PRESS,
     1 UBAR,UFAC,C1,C2,C3,C2VT,ARFAC,ALFAC,APSCN1,APSCN2,PREXP1,CD75,
     2 PREXP2,CR1,CR2,ASEED,MOMCR,RATIO1,RATIO2,RATIO3,RATIO4,RATIO5,
     3 CX,MY,SHOLD,MFU,NCO2,NCO,NOF,NH2O,W34,W3,W4,
     4 WH2,WN,WNO,WN2
C/--------- SUBROUTINE FOR PROGRAM GENMIX 6A
      DIMENSION LAB(2),DUDY(43),G-WP(43),EMUT(43),EMUL(43)
      DIMENSION SUFL(43),SDFU(43)
C
      ENTRY AUXD
C     -------- CALCULATE TURB VISCOSITY FROM TWO EQUATION MODEL --------
      IF (MODEL.EQ.1) GO TO 200
      DO 112 I=1,NP3
      EMUL(I)=EMU(I)
      RT=RHO(I)*F(JE,I)**2/(F(JD,I)*EMUL(I)+1.0E-30)
      CDD=CD*EXP(-2.5/(1.0+RT/50.))
      EMUT(I)=CDD*RHO(I)*F(JK,I)*F(JK,I)/(F(JD,I)+1.0E-30)
      EMU(I)=EMU(I)+EMUT(I)
  112 AMU(I)=EMU(I)
C     ------------------------------------------------ TEST 10
  200 IF (ITEST) 202,201,202
  202 LAB(1)=6HTEST 1
      LAB(2)=6H0
      WRITE (6,100) LAB
      LAB(1)=6HEMU(I)
      LAB(2)=6H-
      WRITE (6,100) LAB,(EMU(I),I=1,NP3)
  201 CONTINUE
C     ----------------- MODIFICATION OF EMU ARRAY
      DO 23 I=2,NP2
   23 EMU(I)=.5*(EMU(I+1)+EMU(I))
      DO 24 I=2,NP1
   24 EMU(I)=EMU(I)/(Y(I+1)-Y(I))
      IF (KRAD.EQ.0) GO TO 300
      DO 26 I=2,NP1
   26 EMU(I)=EMU(I)*.5*(R(I)+R(I+1))
  300 CONTINUE
      RETURN
C     ************************   SOURCE TERMS   ********************
      ENTRY SOURCE
      IF (NV.NE.0) GO TO 500
C     ----- VELOCITY U
      DO 308 I=2,NP2
      SU(I)=-DPDX(I)*.5*RDY(I)
  308 SD(I)=0.
      IF (NFNZ.EQ.0) GO TO 1308
      DO 1309 I=2,NP2
      SU(I)=SU(I)+U(I)*EVAP(I)
 1309 SD(I)=SD(I)-EVAP(I)
 1308 CONTINUE
      GO TO 6000
C     ----------------------- KINETIC HEATING.
  500 IF (NV.NE.JH) GO TO 1000
C     ----- TEMPORARY USE OF SD ARRAY.
      GO TO (303,304), MCVEL
  303 DO 305 I=1,NP3
      SU(I)=0.
  305 SD(I)=0.
      GO TO 306
  304 DO 30 I=2,NP2
   30 SD(I)=U(I)*U(I)
      DO 31 I=2,NP1
   31 SD(I)=EMU(I)*(SD(I+1)-SD(I))
      SD(1)=0.
      SD(NP2)=0.
      DO 32 I=2,NP2
```

```
      T=(1.-1./PREF(I))*.5
   32 SU(I)=(S D(I)-S D(I-1))*T
      DO 33 I=2,NP1
   33 SD(I)=0.
      IF (IFLUX.EQ.0) GO TO 941
      DO 940 I=2,NP2
      FLPTE=SIGMA*FS(JT,I)**4
      SOP=2.*ABSOP*(FS(JPY,I)-FLPTE)
      TO=(FS(JPY,I)/SIGMA)**.25
      T3=TO+.001
      DSDH=SOP/(CP*(FS(JT,I)-T0))
      SU(I)=SU(I)+(SCP-DSDH*F(JH,I))*.5*DY(I)
  940 SD(I)=SD(I)+DSDH*.5*DY(I)
  941 CONTINUE
      IF (NFUZ.EQ.0) GO TO 937
      HPI=HDR(TFUEL,1)
      DO 963 I=2,NP2
      SU(I)=SU(I)+HPI*EVAP(I)
  963 SD(I)=SD(I)-EVAP(I)
  937 CONTINUE
C ---------------------------------------- TEST II
  306 IF(ITEST) 302,301,302
  302 LAB(1)=6HTEST 1
      LAB(2)=1H1
      WRITE(6,100) LAB
      LAB(1)=6HSD(I
      LAB(2)=1H)
      WRITE(6,100) LAB,(SD(I),I=1,NP3)
      LAB(1)=6HSU(I
      LAB(2)=1H)
      WRITE(6,100) LAB,(SU(I),I=1,NP3)
  301 CONTINUE
      GO TO 6000
C ----------------------------------------- ---------------- FUEL ----------
 1000 IF (NV.NE.JFU) GO TO 2000
      DO 98 I=2,NP2
      IF(INERT-1) 45,41,45
   45 F2=F(JFU,I)
      F3=F(JFUOX,I)
      F4=F(JCO,I)
      F6=F(JH,I)
      F7=F(JD,I)
      FS1=F(JOX,I)
      FS2=FS(JT,I)
      IF(I-2) 42,46,42
   46 F2=F2+.25*(F(JFU,3)-F2)
      F3=F3+.25*(F(JFUOX,3)-F3)
      F4=F4+.25*(F(JCO,3)-F4)
      F6=F6+.25*(F(JH,3)-F6)
      F7=F7+.25*(F(JD,3)-F7)
      FS1=FS1+.25*(F(JOX,3)-FS1)
      FS2=FS2+.25*(FS(JT,3)-FS2)
   42 IF(I-NP2) 43,47,43
   47 F2=F2+.25*(F(JFU,NP1)-F2)
      F3=F3+.25*(F(JFUOX,NP1)-F3)
      F4=F4+.25*(F(JCO,NP1)-F4)
      F6=F6+.25*(F(JH,NP1)-F6)
      F7=F7+.25*(F(JD,NP1)-F7)
      FS1=FS1+.25*(F(JOX,NP1)-FS1)
      FS2=FS2+.25*(FS(JT,NP1)-FS2)
   43 IF(F2) 41,41,430
  430 IF(FS1) 41,41,431
  431 SOP1=-PREXP1*RHO(I)**2*FS1*F2*(-ACTN/FS2)
      GO TO (48,49), MODEP
   48 SOP=SOP1
      GO TO 44
   49 SOP2=-CP1*RHO(I)*F7/F6
      SOP=AMAX1(SOP1,SOP2)
   44 SOP1=SOP*F2*.5*DY(I)
      PI=PI*RHO(I)/3.
      IF (-2.*SOP1-PI*F2) 95,95,96
   95 SU(I)=SOP1
      SD(I)=0.
      GO TO 40
   96 FUB=AMAX1(0.,((RATIO1*RATIO2)*F3-RATIO2-RATIO3*F4)/RATIO1)
      IF (F2-FUB) 41,41,94
   94 SSDFU=SOP1/(F2-FUB)
```

SUBROUTINE AUX   73/74   OPT=0 TRACE   FTN 4.6+439   08/24/78 13.44.16   PAGE 3

```
      SU(I)=-DSDFU*FUB
      SD(I)=DSDFU
      GO TO 40
   41 SU(I)=0.
      SD(I)=0.
   40 SUFU(I)=SU(I)
      SDFU(I)=SD(I)
   98 CONTINUE
      IF (NFRZ.EQ.0) GO TO 933
      DO 932 I=2,NP2
      SU(I)=SU(I)+EVAP(I)
  932 SD(I)=SD(I)-EVAP(I)
  933 CONTINUE
C ------------------------------------------ TEST 12
      IF(ITEST) 402,401,402
  402 LAB(1)=6HTEST 1
      LAB(2)=1H2
      WRITE(6,100) LAB
      LAB(1)=6HSD(I)
      LAB(2)=1H)
      WRITE(6,100) LAB,(SD(I),I=1,NP3)
      LAB(1)=6HSU(I
      LAB(2)=1H)
      WRITE(6,100) LAB,(SU(I),I=1,NP3)
  401 CONTINUE
      GO TO 8000
C --------------------------------------------------------- DY-FU*DXFU ----------
 2000 IF (NV.NE.JFJOX) GO TO 3000
      DO 50 I=2,NP2
      SU(I)=0.
   50 SD(I)=0.
      IF (NFRZ.EQ.0) GO TO 931
      DO 1932 I=2,NP2
      SU(I)=SU(I)+EVAP(I)
 1932 SD(I)=SD(I)-EVAP(I)
  931 CONTINUE
      GO TO 6000
C ------------------  SOURCE TERMS FOR CO  ----------------------------
 3000 IF (NV.NE.JCO) GO TO 3500
      FZ=0.
      DO 140 I=2,NP2
      IF (INFPT-1) 145,141,145
  145 F2=F(JFU,I)
      F3=F(JFUOX,I)
      F4=F(JCO,I)
      F6=F(JH,I)
      F7=F(J5,I)
      FS1=F(JOX,I)
      FS2=FS(JT,I)
      IF (I-2) 142,146,142
  146 F2=F2+.25*(F(JFU,3)-F2)
      F3=F3+.25*(F(JFUOX,3)-F3)
      F4=F4+.25*(F(JCO,3)-F4)
      F6=F6+.25*(F(JH,3)-F6)
      F7=F7+.25*(F(JC,3)-F7)
      FS1=FS1+.25*(F(JCX,3)-FS1)
      FS2=FS2+.25*(FS(JT,3)-FS2)
  142 IF (I-NP2) 143,147,143
  147 F2=F2+.25*(F(JFU,NP1)-F2)
      F3=F3+.25*(F(JFUOX,NP1)-F3)
      F4=F4+.25*(F(JCO,NP1)-F4)
      F6=F6+.25*(F(JH,NP1)-F6)
      F7=F7+.25*(F(JC,NP1)-F7)
      FS1=FS1+.25*(F(JOX,NP1)-FS1)
      FS2=FS2+.25*(FS(JT,NP1)-FS2)
  143 IF (F4) 141,141,1430
 1430 IF (FS1) 141,141,1431
 1431 SOP1=-P*EXPZ*P*C(I)**Z*FS1*EXP(-ARCT*P/FS2)
      GO TO (148,149), MODE
  148 SOP=SOP1
      GO TO 144
  149 SOP2=-CP2*RHO(I)*F7/F6
      SOP=AMAX1(SOP1,SOP2)
  144 SOP1=SOP*F4*.5*DCV(I)
      PX=PEI*BD*(I)/DX
      IF (-2.*SOP1-PX*F4) 345,945,946
  945 SU(I)=SOP1-RATIC4*(SUFU(I)+SD*FU(I)*F2)
```

```
      SD(I)=0.
      GO TO 140
  946 FUB=AMAX1(0.,((RATIO1+RATIO2)*F3-RATIO2-RATIO1*F2)/RATIO3)
      IF (F4-FUB) 141,141,944
  944 DSDCO=SDP1/(F4-FUB)
      SU(I)=-DSDCO*FUB-RATIO4*(SUFU(I)+SDFU(I)*F2)
      SD(I)=DSDCO
      GO TO 140
  141 SU(I)=-RATIO4*(SUFU(I)+SDFU(I)*F2)
      SD(I)=0.
  140 CONTINUE
      IF (NFNZ.EQ.0) GO TO 929
      DO 926 I=2,NP2
  926 SD(I)=SD(I)-EVAP(I)
  929 CONTINUE
C ------------------------------------------------------------ TEST 13
      IF (ITEST) 178,179,178
  178 LAB(1)=6HTEST 1
      LAB(2)=6H3
      WRITE (6,100) LAB
      LAB(1)=6HSU(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(SU(I),I=1,NP3)
      LAB(1)=6HSD(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(SD(I),I=1,NP3)
  179 CONTINUE
      GO TO 6000
C -----------       SWIRL VELOCITY    ----------------
 3500 IF (NV.NE.JVT) GO TO 4000
      DO 60 I=2,NP2
      SU(I)=0.0
   60 SD(I)=0.0
      IF (NFNZ.EQ.0) GO TO 1315
      DO 1316 I=2,NP2
 1316 SU(I)=SU(I)+F(JVT,I)*EVAP(I)
 1315 CONTINUE
      GO TO 6000
C -----------        TURBULENT KINETIC ENERGY     ------------------
 4000 IF (NV.NE.JK) GO TO 5000
      D22=Y(3)-Y(1)
      VT2=F(JVT,2)/(.75*R(2)+.25*R(3))
      VT3=F(JVT,3)/R(3)
      RK2=SQRT(F(JK,2))
      RK3=SQRT(F(JK,3))
      DUDY(2)=(U(3)-U(2))/D22
      DVTDY=(VT3-VT2)/D22
      DK2=(RK3-RK2)/D22
      GENP(2)=DUDY(2)**2+(DVTDY-VT2/(.75*R(2)+.25*R(3)))**2
C ---------------------------
      DO 70 I=3,NP1
      D11=D22
      D22=Y(I+1)-Y(I)
      IF (I.EQ.NP1) D22=Y(NP3)-Y(NP1)
      D12=D11+D22
      DUDY(I)=D11*(U(I+1)-U(I))/(D12*D22)+D22*(U(I)-U(I-1))/(D12*D11)
      VT1=VT2
      VT2=VT3
      VT3=F(JVT,I+1)/R(I+1)
      IF (I.EQ.NP1) VT3=F(JVT,NP3)/(.75*R(NP2)+.25*R(NP1))
      DVTDY=D11*(VT3-VT2)/(D12*D22)+D22*(VT2-VT1)/(D12*D11)
      RK1=RK2
      RK2=RK3
      RK3=SQRT(F(JK,I+1))
      DRKDY=D11*(RK3-RK2)/(D12*D22)+D22*(RK2-RK1)/(D12*D11)
      GENP(I)=DUDY(I)**2+(DVTDY-VT2/R(I))**2
      SU(I)=EMUT(I)*GENP(I)
   70 SD(I)=-(2*MU(I)*F(JD,I)+2.*EMU(L(I)*DRKDY**2))/F(JK,I)
C ---------------------------
      DUDY(NP2)=(U(NP2)-U(NP1))/D22
      DVTDY=(VT3-VT2)/D22
      DKNP2=(RK3-RK2)/D22
      GENP(NP2)=DUDY(NP2)**2+(DVTDY-VT3/(.75*R(NP2)+.25*R(NP1)))**2
      F6=.75*F(JK,2)+.25*F(JK,3)
      F7=.75*F(JD,2)+.25*F(JD,3)
      SU(2)=EMUT(2)*GENP(2)
      SD(2)=-(R*MU(2)*F7+2.*EMU(2)*DK2**2)/F6
```

```
      F6=.75*F(JK,NP2)+.25*F(JK,NP1)                              AU    297
      F7=.75*F(JD,NP2)+.25*F(JD,NP1)                              AU    298
      SU(NP2)=EMUT(NP2)*GENR(NP2)                                 AU    299
      SD(NP2)=-(RHO(NP2)*F7+2.*EMU(NP2)*D*NP2**2)/F6              AU    300
   76 DO 77 I=2,NP2                                               AU    301
      SU(I)=SU(I)*0.5*DY(I)                                       AU    302
   77 SD(I)=SD(I)*0.5*DY(I)                                       AU    303
      IF (NFNZ.EQ.0) GO TO 1310                                   AU    304
      DO 1311 I=2,NP2                                             AU    305
      SU(I)=SU(I)+F(JK,I)*EVAP(I)                                 AU    306
 1311 SD(I)=SD(I)-EVAP(I)                                         AU    307
 1310 CONTINUE                                                    AU    309
C     ------------------------------------------  TEST 13         AU    309
      IF (ITEST) 78,79,78                                         AU    310
   78 LAB(1)=6HTEST 1                                             AU    311
      LAB(2)=6H3                                                  AU    312
      WRITE (6,103) LAB                                           AU    313
      LAB(1)=6HSU(I                                               AU    314
      LAB(2)=6H)                                                  AU    315
      WRITE (6,100) LAB,(SU(I),I=1,NP3)                           AU    316
      LAB(1)=6HSD(I                                               AU    317
      LAB(2)=6H)                                                  AU    318
      WRITE (6,100) LAB,(SD(I),I=1,NP3)                           AU    319
   79 CONTINUE                                                    AU    320
C     ---------------------                                       AU    321
      GO TO 6000                                                  AU    322
C     ---------------  TURBULENCE DISSIPATION  ------------------ AU    323
 5000 IF (NV.NE.JD) GO TO 6000                                    AU    324
      D22=Y(3)-Y(2)                                               AU    325
      DO 90 I=3,NP1                                               AU    326
      C2E=C2                                                      AU    327
      IF (ISOLVE(JVT).EQ.0) GO TO 90                              AU    328
      D11=D22                                                     AU    329
      D22=Y(I+1)-Y(I)                                             AU    330
      D12=D11+D22                                                 AU    331
      DRVTDY=D11*(F(JVT,I+1)-F(JVT,I))/(D12*D22)+D22*(F(JVT,I)-F(JVT,I-1 AU    332
     * ))/(D12*D11)                                               AU    333
      C2E=C2E+C2/T*(F(JVT,I)/R(I)**3)*DRVTDY/(GENR(I)+1.0E-20)    AU    334
      C2E=AMIN1(C2E,3.)                                           AU    335
      C2E=AMAX1(C2E,1.)                                           AU    336
   90 DUDYDY=(DUDY(I+1)-DUDY(I-1))/(Y(I+1)-Y(I-1))                AU    337
      FACTOR=2.*EMUL(I)*EMUT(I)*DUDYDY*DUDYDY/RHO(I)              AU    338
      SU(I)=C1*F(JD,I)*EMUT(I)*GENR(I)/F(JK,I)+FACTOR             AU    339
   95 SD(I)=-C2E*F(JD,I)*RHO(I)/F(JK,I)                           AU    340
C     ------------------                                          AU    341
      F6=.75*F(JK,2)+.25*F(JK,3)                                  AU    342
      F7=.75*F(JD,2)+.25*F(JD,3)                                  AU    343
      GO TO (81,82,82), KIN                                       AU    344
   81 IF (RMI.GT.1.E-10) GO TO 82                                 MM      1
      SU(2)=1.E30*CD75*F6**1.5/(YI*AK)                            MM      2
      SD(2)=-1.E30                                                AU    346
      GO TO 83                                                    AU    347
   82 SU(2)=C1*F7*EMUT(2)*GENR(2)/F6                              AU    348
      SD(2)=-C2*F7*RHO(2)/F6                                      AU    349
   83 F6=.75*F(JK,NP2)+.25*F(JK,NP1)                              AU    350
      F7=.75*F(JD,NP2)+.25*F(JD,NP1)                              AU    351
      GO TO (84,85,85), KEX                                       AU    352
   84 IF (RME.LT.-1.E-10) GO TO 85                                MM      3
      SU(NP2)=1.E30*CD75*F6**1.5/(YE*AK)                          MM      4
      SD(NP2)=-1.E30                                              AU    354
      GO TO 86                                                    AU    355
   85 SU(NP2)=C1*F7*EMUT(NP2)*GENR(NP2)/F6                        AU    356
      SD(NP2)=-C2*F7*RHO(NP2)/F6                                  AU    357
   86 DO 87 I=2,NP2                                               AU    358
      SU(I)=SU(I)*0.5*DY(I)                                       AU    359
   87 SD(I)=SD(I)*0.5*DY(I)                                       AU    360
      IF (NFNZ.LE.0) GO TO 1312                                   AU    361
      DO 1313 I=2,NP2                                             AU    362
      SU(I)=SU(I)+F(JD,I)*EVAP(I)                                 AU    363
 1313 SD(I)=SD(I)-EVAP(I)                                         AU    364
 1312 CONTINUE                                                    AU    365
C     ------------------------------------------  TEST 14         AU    366
      IF (ITEST) 88,89,88                                         AU    367
   88 LAB(1)=6HTEST 1                                             AU    368
      LAB(2)=6H4                                                  AU    369
      WRITE (6,103) LAB                                           AU    370
      LAB(1)=6HSU(I                                               AU    371
```

```
SUBROUTINE AUX        73/74   OPT=0 TRACE                    FTN 4.6+439      09/24/79  13.44.16       PAGE    6

                 LAB(2)=6H)                                                         AU        372
                 WRITE (6,100) LAB,(SU(I),I=1,NP3)                                  AU        373
                 LAB(1)=6HSD(I                                                      AU        374
                 LAB(2)=6H)                                                         AU        375
                 WRITE (6,100) LAB,(SD(I),I=1,NP3)                                  AU        376
              89 CONTINUE                                                           AU        377
C                                                                                   AU        378
            6000 CONTINUE                                                           AU        379
                 RETURN                                                             AU        380
             100 FORMAT(1H ,A5,A2,1P11E11.3/(7X,11E11.3))                           AU        381
                 END                                                                AU        382

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

    86      I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   141      I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   223      I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   356      I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   365      I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
```

```
      SUBROUTINE DROP                                                      AUS     2
      COMMON/COMA/A(43),AJE(16),AJI(16),B(43),C(43),CSALFA,C(43),          COMA    2
     1 DPDX(43),DX,EMU(43),F(16,43),FS(3,43),IAX,IFND,IFIN,INDE(16),       COMA    3
     2 INDI(16),IOUT,ISTEP,ITEST,IJTRAP,JS,JSW,JW,JY,KEX,KIN,KRAD,N,       COMA    4
     3 NO2,NF,NOVEL,NP1,NP2,NP3,PM(43),OMO(43),P(43),PEI,PP(16),           COMA    5
     4 PREF(16),PSIE,PSII,R(43),RHO(43),RU(43),RME,RMI,SD(43),SU(43),      COMA    6
     5 TAUE,TAUI,U(43),XD,XU,Y(43),YE,YI,PSOPL(43),RDY(43),ISOLVE(16),     COMA    7
     6 US(43),AMU(43),SUM1,SUM2,SUM3,SUM4,PDGECN,FDIFI(16),FDIFE(16),      COMA    8
     7 GE(16),GI(16),JLOC(12),W(12),JH,JFU,JCO2,JCO,JOX,JH2O,JOH,JO,JHS,   COMA    9
     8 JH2,JN,JNO,JN2,JVT,JD,JK,JT,JRY,NSP,NSPM,ASSOP,SCATR,BOM(200),      COMA   10
     9 EPI,SIGMA,CP,JFUOX,IFLUX,EVAP(43),TFJEL,NFNZ                        COMA   11
      COMMON/COMB/AF,ALPG,EWALL,FB,G,AFU,FMIET,MASSTR,MODEL,PRESS,         COMB    2
     1 USAR,UFAC,C1,C2,CG,C2VT,AKFAC,ALFAC,ARCON1,ARCON2,PREXP1,CO75,      COMB    3
     2 PREXP2,CR1,CR2,MODER,MODCP,RATIO1,RATIO2,RATIO3,RATIO4,RATIO5,      COMB    4
     3 CX,HY,DXOLD,WFU,WCO2,WCO,WOX,WH2O,WO4,WO,W4,                        COMB    5
     4 WH2,WN,WNO,WN2                                                      COMB    6
      DIMENSION YDL(5),UFD(5),VFD(5),DD(5),FEVAP(5),DO(5),PC(4),E(4)       AUS     5
      DIMENSION DSMD(5),FRACT(7),RW(7),RWCOND(4),ACOND(4),BCOND(4)         AUS     6
      DATA DSMD/.6,.9,1.2,1.5,2.1/,FRACT/0.,.1,.3,.5,.7,.9,1.0/            AUS     7
      DATA PC/2.79E+8,9.79E+8,2.15E+9,4.8E+9/                              AUS     8
      DATA ACOND/-5.302E-3,-6.358E-3,-6.296E-3,-6.91E-3/                   AUS     9
      DATA BCOND/5.36E-5,4.91E-5,4.64E-5,4.73E-5/                          AUS    10
      DATA RW/96.28,114.6,126.51,139.15,150.59,173.21,294.76/              AUS    11
      DATA RWCOND/50.,100.,150.,300./,E/2665.,3494.,4007.,4514./           AUS    12
C ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** **                    AUS    13
      IF (ISTEP.GT.0) GO TO 10                                             AUS    14
      READ (5,15) NFNZ,XDP,YDP,UF,VF,SMD,FNOZFLO,TFUEL                     AUS    15
   15 FORMAT (I2,8X,7E10.4)                                                AUS    16
      DO 20 I=1,5                                                          AUS    17
      YDL(I)=YDP                                                           AUS    18
      UFD(I)=UF                                                            AUS    19
      VFD(I)=VF                                                            AUS    20
      FEVAP(I)=0.                                                          AUS    21
      DD(I)=DSMD(I)*SMD*1.E-6                                              AUS    22
   20 DO(I)=DD(I)                                                          AUS    23
   10 CONTINUE                                                             AUS    24
      TF=2300.                                                             AUS    25
      SC=0.8                                                               AUS    26
      BB=0.                                                                AUS    27
      RHODO=0.775                                                          AUS    28
      POT=PC(I)                                                            AUS    29
      ET=E(I)                                                              AUS    30
      TB=ET/ALOG(POT/PRESS)                                                AUS    31
      RDFD=1000.*(RHODO+.208-.00072*TB)                                    AUS    32
      DCOMB=4.5E+7                                                         AUS    33
      DEVAP=3.3E+5                                                         AUS    34
      SMALL=1.E-20                                                         AUS    35
      DO 19 I=1,NP3                                                        AUS    36
   19 EVAP(I)=0.                                                           AUS    37
      JKSTORE=JK                                                           AUS    38
      IF (NFNZ.EQ.0.OR.XU.LT.XDP) RETURN                                   AUS    39
   60 DO 370 I=1,5                                                         AUS    40
C ---------- S T A R T  O F  M A I N  L O O P ----------------------        AUS    41
      IF (FEVAP(I).GE.0.99) GO TO 370                                      AUS    42
      DXFD=0.0                                                             AUS    43
C ----- FIND CELL OCCUPIED BY THE ITH DROPLET -----                        AUS    44
  110 DO 140 J=3,NP1                                                       AUS    45
      YP=0.5*(Y(J+1)+Y(J))                                                 AUS    46
      YM=0.5*(Y(J)+Y(J-1))                                                 AUS    47
      IF (YDL(I).GE.YP.OR.YDL(I).LE.YM) GO TO 120                          AUS    48
      JK=J                                                                 AUS    49
      GO TO 170                                                            AUS    50
  120 IF (YDL(I).NE.YM) GO TO 130                                          AUS    51
      IF (VFD(I).GE.0.0) JK=J                                              AUS    52
      IF (VFD(I).LT.0.0) JK=J-1                                            AUS    53
      GO TO 170                                                            AUS    54
  130 IF (YDL(I).NE.YP) GO TO 140                                          AUS    55
      IF (VFD(I).GE.0.0) JK=J+1                                            AUS    56
      IF (VFD(I).LT.0.0) JK=J                                              AUS    57
      GO TO 170                                                            AUS    58
  140 CONTINUE                                                             AUS    59
  150 IF (YDL(I).GE.0.5*(Y(3)+Y(2))) GO TO 160                             AUS    60
      JK=2                                                                 AUS    61
      YP=0.5*(Y(JK+1)+Y(JK))                                               AUS    62
      YM=0.0                                                               AUS    63
      GO TO 175                                                            AUS    64
  160 IF (YDL(I).LE.(Y(NP2)+Y(NP1))/2.) GO TO 170                          AUS    65
```

```
      JK=NP2
      YP=Y(NP3)
      YM=0.5*(Y(JK)+Y(JK-1))
C ----- FREESTREAM PROPERTIES -----
  170 ROST=RHO(JK)
      TST=FS(JT,JK)
      VISC=VISCO(TST)
      UST=U(JK)
      VST=0.0
C ------------- P R O P E R T I E S  O F  F U E L ------------------
C ----- BOILING TEMPERATURE -----
      FOT=PD(4)
      ET=E(4)
      IF (FEVAP(I).GE.0.5) GO TO 180
      POT=TAB(FEVAP(I),FRACT,PO,4)
      ET=TAB(FEVAP(I),FRACT,E,4)
  180 TB=ET/ALOG(POT/PRESS)
      TI=(TB+TF)/2.
C ----- DENSITY OF LIQUID FUEL AT TB -----
      ROF=1.076/(1.+(1.076/.775-1.)*(1.-.67*FEVAP(I)))
      ROF=1000.*(ROF+.208-.00072*TB)
C ----- MOLECULAR WEIGHT OF FUEL VAPORS -----
      RWT=TAB(FEVAP(I),FRACT,RW,7)
      AT=TAB(RWT,RWCOND,ACOND,4)
      BT=TAB(RWT,RWCOND,BCOND,4)
C ----- THERMAL CONDUCTIVITY AND SPECIFIC HEAT OF FUEL VAPORS -----
      COND1=1.729*(AT+BT*TI)
      CPI=4184.*(0.1534+.00081*TI)
      COND1=0.4*COND1+0.6*.064*SQRT(TI/1111.)
C ----- RELATIVE VEL,REYNOLDS NO.,DRAG COEF AND FORCE COMPONENTS -----
      VR=SQRT((UFO(I)-UST)**2+(VFO(I)-VST)**2)
      REI=ROST*VR*DD(I)/VISC
      CDS=0.32+4.4/SQRT(REI)+24./REI
      CDI=AMAX1(CDS/2.,CDS/(1.+BR))
      FCTR=CDI*3.14159/4.*DD(I)**2/2.*ROST
      UF=UFO(I)
      VF=VFO(I)
      DS1=AMIN1(DX,YP-YM)
      KOUNT=0
C     -----------------
      IF (ITEST.EQ.0) GO TO 193
      LAB=BHDROPI
      WRITE (6,980) LAB,POT,ET,TB,ROF,RWT,COND1,VR,CD,FCTR,DS1
  980 FORMAT (/1H ,A3,1P11E11.3/(9X,11E11.3))
C     -----------------
  190 KOUNT=KOUNT+1
      IF (KOUNT.LT.15) GO TO 193
      LAB=BHDROPI
      RSTEP=ISTEP
      WRITE (6,980) LAB,DS,DS1,UFA,VFA,    FX,FY,    DTI,FCTR,CONS,
     *  YADX,YP,YM,DXF,DYF,RSTEP
  193 CONTINUE
      IF (KOUNT.GT.20) GO TO 245
      IF (KOUNT.LE.10) DS=DS1
      IF (KOUNT.GT.10) DS=0.5*(DS+DS1)
      UFA=0.5*(UF+UFO(I))
      VFA=0.5*(VF+VFO(I))
      FX=FCTR*ABS(UST-UFA)*(UST-UFA)
      FY=FCTR*ABS(VST-VFA)*(VST-VFA)
      DTI=DS/SQRT(UFA*UFA+VFA*VFA)
      CONS=ROF*3.14159/6.*DD(I)**3/DTI
C ----- VELOCITY AND LOCATION OF DROPLET -----
      UFO(I)=UF+FX/CONS
      VFO(I)=VF+FY/CONS
      DXF=(UFO(I)+UF)/2.*DTI
      DYF=(VFO(I)+VF)/2.*DTI
C ----- ADJUST DS DEPENDING UPON BOUNDARY HIT -----
      DYADX=DYF*(DX-DXFO)/(DXF+SMALL)
      YADX=YOL(I)+DYADX
  200 IF (YADX.GT.YP) GO TO 230
      IF (YADX.LT.YM) GO TO 220
  210 DXF=DX-DXFO
      DYF=DYADX
      IBOUND=0
      GO TO 240
  220 DYM=YM-YOL(I)
      DXF=(DX-DXFO)*DYM/(DYADX+SMALL)
```

```
      DYF=DYM
      IBOUND=-1
      GO TO 240
  230 DYP=YP-YDL(I)
      DXF=(DX-DXFO)*DYP/(DYACY+SMALL)
      DYF=DYP
      IBOUND=1
  240 DS1=SQRT(DXF*DXF+DYF*DYF)
      IF (ABS(DS1-DS).GT.ABS(.01*DS1)) GO TO 190
  245 YDL(I)=YDL(I)+DYF
      DXFO=DXFO+DXF
      IF (IBOUND) 260,310,270
  260 YDL(I)=YP-.0025*(Y(JK+1)-Y(JK-1))
      GO TO 310
  270 YDL(I)=YP+.0025*(Y(JK+1)-Y(JK-1))
  310 IF (YDL(I).LT.Y(NP3).AND.YDL(I).GT.Y(1)) GO TO 300
      DEVAP=1.0-FEVAP(I)
      FEVAP(I)=1.0
      GO TO 320
C ------ CALCULATE BURNING RATE CONSTANT ------
C --- MASS TRANSFER NC ---
  300 BB=(F(JOX,JK)*GCOMB/RATIO1+AMAX1(CP1*(TST-TB),0.))/QEVAP
      RATE=8./ROF*COND1/CP1*ALOG(1.+BB)*(1.+0.276*SQRT(REI)*SC**.33)
C ------ FRACTION EVAPORATED ------
      DEVAP=1.5/ROFO/DO(I)**3*ROF*DO(I)*RATE*DS/SQRT(UFO(I)**2+VFO(I)**2
     1)
      FEVAP(I)=FEVAP(I)+DEVAP
      IF (FEVAP(I).LE.1.00) GO TO 320
      DEVAP=DEVAP-(FEVAP(I)-1.00)
      FEVAP(I)=1.00
  320 EVAP(JK)=EVAP(JK)+DEVAP
C ------ NEW DROPLET DIAMETER ------
      ARG=DD(I)*DD(I)-RATE*DTI
      IF (ARG.LE.0.0) GO TO 330
      DD(I)=SQRT(ARG)
      GO TO 340
  330 DD(I)=0.0
      FEVAP(I)=1.0
C   ------------------
      IF (ITEST.EQ.0) GO TO 340
      LAB=8HDROP2
      WRITE (6,980)  LAB,UFO(I),VFO(I),          YDL(I),DXFO,
     1               DEVAP,FEVAP(I),DD(I),BB,RATE
C   ------------------
  340 IF (DXFO.LT..99*DX.AND.FEVAP(I).LT.0.99) GO TO 110
  370 CONTINUE
      DO 390 I=2,NP2
      EVAP(I)=EVAP(I)*FNOZFLO/5./DX
  390 CONTINUE
      JK=JKSTORE
C   ------------------
      RETURN
      END
```

```
      FUNCTION GASP (TT,I)
      DIMENSION AH(7,12),AL(7,12),W(12)
C
C     SPECIES ORDER - FUEL,CO2,CO,O2,H2O,OH,O,H,H2,N,NO,N2
C
      DATA ((AH(I,J),I=1,7),J=1,6)/
     1 0.26845936E+02, 0.46470050E-01,-0.22767813E-04, 0.48494616E-08,
     2-0.37080219E-12,-0.40857112E+05, 0.            ,
     3  .44608041E+01,  .30981719E-02, -.12392571E-05,  .22741325E-09,
     4 -.15525954E-13, -.48961442E+05, -.98535982E+00,
     5  .29840696E+01,  .14891390E-02, -.57899684E-06,  .10364577E-09,
     6 -.69353550E-14, -.14245228E+05,  .63479156E+01,
     7  .36219535E+01,  .73618264E-03, -.19652229E-06,  .36201558E-10,
     8 -.28945627E-14, -.12019825E+04,  .36150960E+01,
     9  .27167633E+01,  .29451374E-02, -.80224374E-06,  .10226682E-09,
     * -.48472145E-14, -.29905826E+05,  .66305671E+01,
     1  .29131230E+01,  .95418248E-03, -.19086325E-06,  .12730795E-10,
     2  .24803941E-15,  .39647060E+04,  .54288735E+01/
C
      DATA ((AH(I,J),I=1,7),J=7,12)/
     1  .25420596E+01, -.27550619E-04, -.31028033E-08,  .45510674E-11,
     2 -.43680515E-15,  .29230803E+05,  .49203080E+01,
     3  .25000000E+01, 0.            , 0.            , 0.            ,
     4 0.            ,  .25471627E+05, -.46011743E+00,
     5  .31001901E+01,  .51119464E-03,  .52644210E-07, -.34909973E-10,
     6  .36945345E-14, -.87738042E+03, -.19629421E+01,
     7  .24502682E+01,  .10661458E-03, -.74653373E-07,  .18796524E-10,
     8 -.10259839E-14,  .56116040E+05,  .44487591E+01,
     9  .31890000E+01,  .13382281E-02, -.52899318E-06,  .95919332E-10,
     * -.64847932E-14,  .98283290E+04,  .67458126E+01,
     1  .28963194E+01,  .15154866E-02, -.57235277E-06,  .99807393E-10,
     2 -.65223555E-14, -.90586184E+03,  .61615148E+01/
C
      DATA ((AL(I,J),I=1,7),J=1,6)/
     1 0.57799475E+01, 0.50561445E-01, 0.51144255E-04,-0.94988140E-07,
     2 0.39603875E-10,-0.29323487E+05, 0.            ,
     3  .24007797E+01,  .87350957E-02, -.66070878E-05,  .20021861E-08,
     4  .63274039E-15, -.48377527E+05,  .96951457E+01,
     5  .37100928E+01, -.16190964E-02,  .36923594E-05, -.20319674E-08,
     6  .23953344E-12, -.14356310E+05,  .29555351E+01,
     7  .36255985E+01, -.18782184E-02,  .70554544E-05, -.67635137E-08,
     8  .21555993E-11, -.10475226E+04,  .43052778E+01,
     9  .40701275E+01, -.11084499E-02,  .41521180E-05, -.29637404E-08,
     *  .80702103E-12, -.30279722E+05, -.32270046E+00,
     1  .38365518E+01, -.10702314E-02,  .94549757E-06,  .18713972E-09,
     2 -.22571094E-12,  .36412823E+04,  .49370009E+00/
C
      DATA ((AL(I,J),I=1,7),J=7,12)/
     1  .29464287E+01, -.16381665E-02,  .24210316E-05, -.16028432E-08,
     2  .38906964E-12,  .29147644E+05,  .29639949E+01,
     3  .25000000E+01, 0.            , 0.            , 0.            ,
     4 0.            ,  .25471627E+05, -.46011762E+00,
     5  .30574451E+01,  .26765200E-02, -.58099162E-05,  .55210391E-08,
     6 -.18122739E-11, -.98890474E+03, -.22997056E+01,
     7  .25030714E+01, -.21800181E-04,  .54205287E-07, -.56475602E-10,
     8  .20999044E-13,  .56098904E+05,  .41675764E+01,
     9  .40459521E+01, -.34181783E-02,  .79819190E-05, -.61139316E-08,
     *  .15919076E-11,  .97453934E+04,  .29974988E+01,
     1  .36748261E+01, -.12081500E-02,  .23240102E-05, -.63217559E-09,
     2 -.22577253E-12, -.10611588E+04,  .23580424E+01/
C
      DATA W/44.,44.,28.,32.,18.,17.,16.,1.,2.,14.,30.,28./,KOUNT/0/
      DATA TLIM/1500./
C ****************************************************************
      ENTRY GTT
      T=TT
      IF (T.LT.1000.) GO TO 10
      ARG=AH(1,I)*(1.-ALOG(T))+AH(6,I)/T-(AH(7,I)+T*(AH(2,I)/2.+T*(AH(3,
     1I)/6.+T*(AH(4,I)/12.+T*AH(5,I)/20.))))
      GO TO 15
   10 ARG=AL(1,I)*(1.-ALOG(T))+AL(6,I)/T-(AL(7,I)+T*(AL(2,I)/2.+T*(AL(3,
     1I)/6.+T*(AL(4,I)/12.+T*AL(5,I)/20.))))
   15 GASP=ARG
      RETURN
C ****************************************************************
      ENTRY CPOR
      T=TT
```

```
      IF (I.EQ.1) T=AMIN1(T,TLIM)
      IF (T.LT.1000.) GO TO 20
      ARG=AH(1,I)+T*(AH(2,I)+T*(AH(3,I)+T*(AH(4,I)+T*AH(5,I))))
      GO TO 25
   20 ARG=AL(1,I)+T*(AL(2,I)+T*(AL(3,I)+T*(AL(4,I)+T*AL(5,I))))
   25 GASP=ARG*1.987*4184./W(I)
      RETURN
C     ****************************************************************
      ENTRY HOR
      T=TT
      IF (I.EQ.1) T=AMIN1(T,TLIM)
      IF (T.LT.1000.) GO TO 30
      ARG=AH(6,I)+T*(AH(1,I)+T*(AH(2,I)/2.+T*(AH(3,I)/3.+T*(AH(4,I)/4.+T
     1*AH(5,I)/5.))))
      GO TO 35
   30 ARG=AL(6,I)+T*(AL(1,I)+T*(AL(2,I)/2.+T*(AL(3,I)/3.+T*(AL(4,I)/4.+T
     1*AL(5,I)/5.))))
   35 GASP=ARG*1.987*4184./W(I)
      IF (TT.LT.TLIM.OR.I.NE.1) RETURN
      CPI=AH(1,I)+T*(AH(2,I)+T*(AH(3,I)+T*(AH(4,I)+T*AH(5,I))))
      ARG=ARG+CPI*(TT-T)/W(I)
      GASP=ARG*1.987*4184./W(I)
      RETURN
C     ****************************************************************
      ENTRY COEF
      KOUNT=KOUNT+1
      IF (KOUNT.EQ.2) GO TO 40
      W(I)=TT
      GASP=W(I)
      RETURN
   40 HFU=TT
      AH(6,I)=HFU/1.987
      AL(6,I)=HFU/1.987
      GASP=AL(6,I)
      RETURN
      END
```

```
      SUBROUTINE STRAD                                                   SA      115
      COMMON/COMA/A(43),AJE(14),AJT(14),R(43),C(43),CSALFA,D(43),        COMA      2
     1 DPDX(43),DX,EMU(43),F(16,43),FT(3,43),IAX,IEND,IFIN,INDE(16),     COMA      3
     2 INDI(16),IOUT,ISTEP,ITEST,IJTRAP,JS,JSW,JV,JY,KEX,KIN,KRAD,N,     COMA      4
     3 N02,NF,NOVEL,NP1,NP2,NP3,OM(43),OMD(43),P(43),PEI,PR(16),         COMA      5
     4 PREF(16),PSIE,PSII,R(43),RHO(43),RU(43),RME,RMI,SD(43),SU(43),    COMA      6
     5 TAUE,TAUI,U(43),UD,UV,Y(43),YE,YI,PSWPL(43),RCV(43),ISOLVE(16),   COMA      7
     6 US(43),AMU(43),SUM1,SUM2,SUM3,SUM4,POSCON,FDIFF(16),FDIFE(16),    COMA      8
     7 GE(16),GI(16),JLOC(12),J(12),JH,JEH,JCO2,JCO,JOX,JH2O,JOH,JO,JHS, COMA      9
     8 JH2,JN,JNO,JN2,JVT,JE,JK,JT,JRV,NSP,NFP,ABSOR,SCATR,EOP(200),     COMA     10
     9 EMI,SIGMA,CP,JFUDI,IFLUX,EYAP(43),TFUEL,NFMT                      COMA     11
      COMMON/COMB/AM,ALPG,EWALL,FR,H,HFU,INERT,MASSTR,MODEL,PRESS,       COMB      2
     1 UBAR,UFAC,C1,C2,CD,C2VT,AMFAC,ALFAC,ABCON1,ABCON2,PREIP1,C075,    COMB      3
     2 PREXP2,CP1,CP2,POWER,MODCP,RATIO1,RATIO2,RATIO3,RATIO4,RATIO5,    COMB      4
     3 CA,HY,DXOLD,WFU,WCO2,WCO,WOX,WH2O,WOH,WO,WH,                      COMB      5
     4 WH2,WN,WNO,WN2                                                    COMB      6
      DIMENSION AYP(200),AYM(200),GAM(200)                               SA      118
      IF (ISTEP.EQ.0) RETURN                                             SA      119
C --------COMPUTE GAMA RADIATION                                         SA      120
      DO 10 I=2,NP3                                                      SA      121
      GAM(I)=1./(ABSOR+SCATR+1./(R(I)+1.E-20))                           SA      122
   10 CONTINUE                                                           SA      123
C --------COMPUTE RADIATION SOURCE TERMS                                 SA      124
      DO 20 I=2,NP2                                                      SA      125
      FLRE=SIGMA*FS(JT,I)**4                                             SA      126
      SU(I)=ABSOR*FLRE                                                   SA      127
      SD(I)=-ABSOR                                                       SA      128
   20 CONTINUE                                                           SA      129
C --------COMPUTE BOUNDARY MODIFICATIONS                                 SA      130
      IF (KIN.NE.1) GO TO 32                                             SA      131
      SU(2)=SU(2)+EMI*SIGMA*FS(JT,1)**4                                  SA      132
      SD(2)=SD(2)-EMI                                                    SA      133
   32 IF (KEX.NE.1) GO TO 34                                             SA      134
      SU(NP2)=SU(NP2)+EMI*SIGMA*FS(JT,NP3)**4                            SA      135
      SD(NP2)=SD(NP2)-EMI                                                SA      136
C --------COMPUTE COEFFICIENTS                                           SA      137
   34 TT=0.                                                              SA      138
      DO 30 I=2,NP2                                                      SA      139
      AYM(I)=TT                                                          SA      140
      TT=.25*(R(I+1)+R(I))*(GAM(I+1)+GAM(I))/(Y(I+1)-Y(I))               SA      141
      AYP(I)=TT                                                          SA      142
      SU(I)=SU(I)*.5*(Y(I+1)-Y(I-1))*R(I)                                SA      143
      SD(I)=SD(I)*.5*(Y(I+1)-Y(I-1))*R(I)                                SA      144
   30 CONTINUE                                                           SA      145
      AYP(NP2)=0.                                                        SA      146
C --------SOLVE RADIATION EQUATION                                       SA      147
      A(1)=0.                                                            SA      148
      B(1)=0.                                                            SA      149
      DO 40 I=2,NP2                                                      SA      150
      STORE=AYP(I)+AYM(I)-SD(I)-AYM(I)*A(I-1)                            SA      151
      A(I)=AYP(I)/STORE                                                  SA      152
   40 B(I)=(SU(I)+AYM(I)*B(I-1))/STORE                                   SA      153
      DO 50 II=2,NP2                                                     SA      154
      I=2+NP2-II                                                         SA      155
   50 FS(JRV,I)=A(I)*FS(JRV,I+1)+B(I)                                    SA      156
      RETURN                                                             SA      157
      END                                                                SA      158
```

```
      SUBROUTINE WTEMP (I)                                               WT    2
      COMMON/COMA/A(43),AJE(16),AJI(16),B(43),C(43),CSALFA,D(43),        COMA  2
     1 DPDX(43),DX,EMU(43),F(16,43),FS(3,43),IAX,IEND,IFIN,INDE(16),     COMA  3
     2 INDI(16),IOUT,ISTEP,ITEST,IUTPAP,JS,JSW,JV,JY,KEX,KIN,KRAD,M,     COMA  4
     3 MDZ,MF,MOVEL,MP1,MP2,MP3,OM(43),OMO(43),P(43),PEI,PM(16),         COMA  5
     4 PREF(16),PSIE,PSII,R(43),RHO(43),RD(43),RME,RPI,SD(43),SU(43),    COMA  6
     5 TAUE,TAUI,U(43),XD,XU,Y(43),YE,YI,PSWEL(43),RDY(43),ISOLVE(16),   COMA  7
     6 US(43),AMU(43),SUM1,SUM2,SUM3,SUM4,PDGSCM,FDIFI(16),FDIFE(16),    COMA  8
     7 GE(16),GI(16),JLOC(12),W(12),JM,JFU,JCO2,JCO,JOX,JH2O,JOM,JO,JHS, COMA  9
     8 JH2,JN,JNO,JN2,JVT,JB,JK,JT,JRY,NSP,NSPM,ABSCP,SCATR,BOM(200),    COMA 10
     9 EMI,SIGMA,CP,JFDOX,IFLUX,EVAP(43),TFUEL,MFMT                      COMA 11
      COMMON/COMB/AK,ALMG,EWALL,FR,H,HFU,INERT,MASSTP,MODEL,PRESS,       COMB  2
     1 UBAR,UFAC,C1,C2,CD,C2VT,AKFAC,ALFAC,ARCON1,ARCON2,PREXP1,CD75,    COMB  3
     2 PREXP2,CR1,CR2,MDCER,MDMCP,RATIO1,RATIO2,RATIO3,RATIO4,RATIO5,    COMB  4
     3 CX,HY,DXOLD,WFU,WCO2,WCO,WOX,WH2O,WOM,WO,W4,                      COMB  5
     4 WH2,WN,WNO,WN2                                                    COMB  6
      COMMON/COMC/API(40),ARE(40),XR(40),NBP                             COMC  2
      COMMON/COMD/XUINJ(12),UINJ(12),TUINJ(12),WTUINJ(12),AUINJ(12),     COMD  2
     1 XVINJ(12),UVINJ(12),VINJ(12),WTVINJ(12),TVINJ(12),AVINJ(12),      COMD  3
     2 RUINJ(12),ARUINJ(12),HUINJ(12),XLUINJ(12),TAM(2),VELA(2),         COMD  4
     3 PRAD(2),NUI,NUE,NVI,NVE                                           COMD  5
      DIMENSION RG(4),XDIST(2),LAP(2),PLIP(2)                            WT    7
      DATA XDIST/0.,0./,PLIP/0.,0./                                      WT    8
      DATA XUL,RG/-10000.,1.,1.,1.,1./                                   WT    9
      DATA SIGMA,EMLIN,EMPL/5.575-9,.9,.9/                               WT   10
      IF (ISTEP.EQ.0) RETURN                                             WT   11
      IF (MD2-1) 5,5,6                                                   WT   12
    6 IMP1=3                                                             WT   13
      IMP2=2                                                             WT   14
      KW=1                                                               WT   15
      KR=KIN                                                             WT   16
      NV=NVI                                                             WT   17
      NU=NUI                                                             WT   18
      RW=TAB(XU,XR,ARI,NBP)                                              WT   19
      GO TO 7                                                            WT   20
    5 IMP1=MP1                                                           WT   21
      IMP2=MP2                                                           WT   22
      KW=2                                                               WT   23
      KR=KEX                                                             WT   24
      NV=NVE                                                             WT   25
      NU=NUE                                                             WT   26
      RW=TAB(XU,XR,ARE,NBP)                                              WT   27
    7 XDIST(1)=XDIST(1)+DXOLD                                            WT   28
      XDIST(2)=XDIST(2)+DXOLD                                            WT   29
      SMALL=1.E-20                                                       WT   30
      XUL=XU                                                             WT   31
  400 CONTINUE                                                           WT   32
      IF (XD.GE.XVINJ(NV)) RETURN                                        WT   33
C ------- DETERMINE COOLENT FLOW CONDITIONS                              WT   34
      IF (XU.GE.XLUINJ(NU)) GO TO 30                                     WT   35
   37 AF=.5*ABS(PRAD(KW)**2-RW**2)                                       WT   36
      CVEL=VELA(KW)                                                      WT   37
      CTEP=TAM(KW)                                                       WT   38
      CDEN=PDGSCM/CTEP                                                   WT   39
      FLO=CDEN*CVEL*AF                                                   WT   40
      GO TO 35                                                           WT   41
   30 IF (XU.GE.XUINJ(NU)) GO TO 37                                      WT   42
      XDIST(KW)=0.                                                       WT   43
      PLIP(KW)=XUINJ(NU)-XLUINJ(NU)                                      WT   44
      CVEL=UINJ(NU)                                                      WT   45
      CTEP=AMAX1(TUINJ(NU),TAM(KW))                                      WT   46
      CDEN=PDGSCM/CTEP                                                   WT   47
      FLO=AUINJ(NU)                                                      WT   48
   35 TA4=CTEP**4                                                        WT   49
      TW=FS(JT,I)                                                        WT   50
      IMOF=0                                                             WT   51
  101 TW15=TW**1.5                                                       WT   52
      TW4=TW**4                                                          WT   53
C ****************** COLD SIDE CONVECTION ****************************** WT   54
      IF (IMOF) 33,33,36                                                 WT   55
   33 IF (XU.GE.XLUINJ(NU)) GO TO 50                                     WT   56
   49 XDIST2=XDIST(KW)+PLIP(KW)                                          WT   57
      XDIST2=AMAX1(XDIST2,.001)                                          WT   58
      REI=CDEN*CVEL*XDIST2/VISCO(CTEP)                                   WT   59
      HK4=.0268*CDEN*CP*CVEL/REI**0.2                                    WT   60
      GO TO 34                                                           WT   61
C ------- IMPINGMENT COOLING INSIDE SLOT LIP                             WT   62
```

```
   50 IF (XU.GE.XUINJ(NU)) GO TO 43
      BIC=AF/(ARUINJ(NU)*R(I))
      UFAC=AMIN1(1.,7.*BIC/HUINJ(NU))
      UFAC=AMAX1(SMALL,UFAC)
      UIC=UINJ(NU)*ARUINJ(NU)*SQRT(UFAC)
      REI=UIC*PLIP(KW)*CDEN/VISCO(CTEM)
      RK4=0.36*REI**0.62*1436.*VISCO(CTEM)/PLIP(KW)
   34 QCC=RK4*(TW-CTEM)
      DQCC=RK4
C ****************** COLD SIDE RADIATION ******************************
      IF (INDX) 43,43,44
   43 RK3=SIGMA/(1./EPLIN+RW*(1./EM*L-1.)/PRAD(KW))
   44 QRC=RK3*(TW4-TA4)
      DQRC=4.*RK3*TW15*TW15
C ********************** HOT SIDE RADIATION ****************************
      IF (INDX) 53,53,54
   53 TF=(FS(JRY,INP2)/SIGMA)**.25
      TF15=TF**1.5
      RK1=2.*EMI*SIGMA*TF15
   54 QRH=RK1*(TF15*TF-TW15*TW)
      DQRH=-2.5*RK1*TW15
C ********************* HOT SIDE CONVECTION ***************************
      IF (XU.GE.XUINJ(NU)) GO TO 71
      GO TO (70,75), KW
   70 QCH=-GI(JH)*CP*(TW-FS(JT,INP1))
      DQCH=-GI(JH)*CP
      GO TO 80
   75 QCH=GE(JH)*CP*(FS(JT,INP1)-TW)
      DQCH=-GE(JH)*CP
      GO TO 80
C --------- ENTRAINMENT NOT COMPLETE
   71 IF (INDX) 63,63,64
   63 XDIST2=XDIST(KW)+PLIP(KW)
      XDIST2=AMAX1(XDIST2,.001)
      REI=CDEN*CVEL*XDIST2/VISCO(CTEM)
      RK2=.0268*CDEN*CP*CVEL/REI**0.2
   64 QCH=RK2*(TUINJ(NU)-TW)
      DQCH=-RK2
   80 CONTINUE
C ************** NEWTON RAPHSON SOLUTION PROCEDURE ********************
      FT=QRH*RO(1)+QCH*RO(2)-QRC*RO(3)-QCC*RO(4)
      DFT=DQRH*RO(1)+DQCH*RO(2)-DQRC*RO(3)-DQCC*RO(4)
      TWO=TW
      TW=TWO-FT/DFT
      INDX=INDX+1
C    ------------- PRINTOUT FOR NON-CONVERGENCE
      IF (INDX.LT.20) GO TO 89
      LAB(1)=8HWTEMP
      LAB(2)=6H
      RNDX=ISTEP
      WRITE (6,105) LAB,RNDX,RK1,RK2,RK3,RK4,QRH,QCH,QRC,QCC
      WRITE (6,105) LAB,DQRH,DQCH,DQRC,DQCC
      WRITE (6,105) LAB,FT,DFT,TW,TWO
  105 FORMAT (1H ,A6,A2,1P11E11.3/(9X,11E11.3))
      GO TO 110
C -------- ERROR TEST --------
   89 IF (ABS(TW-TWO).GT.0.001*ABS(TW)) GO TO 101
C ------ COMPUTE NEW COOLENT TEMP ------
      DT=(QRC*RO(3)+QCC*RO(4))*DXIOL*DR(I)/FLO/CP
      CVEL=CVEL*(1.+DT/CTEM)
      CTEM=CTEM+DT
C ------------- UPDATE ANNULUS OR SLOT CONDITIONS --------------
      IF (XU.GE.XLUINJ(NU)) GO TO 100
   99 VELA(KW)=CVEL
      TAN(KW)=CTEM
      GO TO 110
  100 IF (XU.GE.XUINJ(NU)) GO TO 99
      UINJ(NU)=CVEL
      TUINJ(NU)=CTEM
  110 CONTINUE
      IF (KB.EQ.2) RETURN
      FS(JT,I)=TW
      HPI=0.
      DO 203 JJ=1,NSPP
      J=JLOC(JJ)
  203 HPI=HPI+F(J,I)*HOR(TW,JJ)
      F(JH,I)=HPI+FS(JH2,I)*HOR(TW,17)
```

```
      SUBROUTINE WTEMP      73/74   OPT=0 TRACE                  FTN 4.6+439       08/24/79  13.44.16       PAGE    3

     155               RETURN                                                        WT        140
                       END                                                           WT        141


CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM
     131    I                AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
```

```
      SUBROUTINE STRIDE(ISW)
      COMMON/COMA/A(43),AJE(16),AJI(16),R(43),T(43),CSALFA,C(43),
     1 [illegible]
     2 [illegible]
     3 [illegible]
     4 [illegible]
     5 TAVE,TAUI,U(43),[illegible]
     6 [illegible]
     7 [illegible]
     8 [illegible]
     9 [illegible]
C/--------------- SUBROUTINE FOR PROGRAM [illegible] ---------------
C/ THIS SUBROUTINE PERFORMS THE SAME OPERATIONS AS THE ONE IN [illegible]
C  BUT MORE ECONOMICALLY. THE [illegible] ARRAYS ARE [illegible]. SOME
C  OFTEN USED FUNCTIONS OF [illegible] ARE STORED, AND A [illegible] ARRAY SAVES
C  UNNECESSARY ARITHMETIC IN THE TIME OPERATIONS.
C-------------------------------------------------------------------
      DIMENSION [illegible]
      DIMENSION [illegible]
      DIMENSION [illegible]
      DIMENSION [illegible]
      DATA [illegible]
C
      GO TO (1000,2000,3000,4000), ISW
C
C******************************** [illegible] ****************
 1000 IF(ISTEP) 1003,1003,1100
 1003 [illegible]
      [illegible]
      DO 1002 I=2,[illegible]
      [illegible]
      [illegible]
      [illegible]
 1002 [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      IF([illegible]) GO TO 1100
      DO 1001 I=1,[illegible]
 1001 [illegible]
      [illegible]
      [illegible]
      IF(ITEST.NE.0) WRITE([illegible])
C---------------------- [illegible] ----------------------
 1100 DO 1101 I=1,[illegible]
      IF([illegible]) GO TO 1101
      WRITE(6,1150) [illegible]
 1150 FORMAT([illegible] AT [illegible]
     1 [illegible] STRIDE))
      [illegible]
 1101 [illegible]
      [illegible]
      [illegible]
      DO 1102 I=2,[illegible]
 1102 [illegible]
      IF(ITEST.NE.0) WRITE([illegible])
C---------------------- [illegible] ----------------------
C   ---------------------------- [illegible] FOR PLANE GEOMETRY
      [illegible]
      [illegible]
      [illegible]
      DO 1103 I=[illegible]
 1103 [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      IF([illegible]) RETURN
C   ---------------- [illegible]
      IF(CSALFA.[illegible]) GO TO [illegible]
C   ---------------------------- [illegible]
      [illegible]
      IF([illegible]) GO TO [illegible]
C---------------------------- [illegible]
      DO [illegible]
      [illegible]
```

```
 1106 R(I)=Y(I)*CSALFA
      YI=SQRT(ABS(YI/COSD2))
      YN15=SQRT(ABS(YN15/COSD2))
      GO TO 1107
C     ------------------------------------------  R(1) NE 0.
 1105 R1D2=.5*R(1)
      R1D2SQ=R1D2*R1D2
      DO 1104 I=2,NP3
      Y(I)=Y(I)/(R1D2+SQRT(ABS(R1D2SQ+COSD2*Y(I))))
 1104 R(I)=R(1)+Y(I)*CSALFA
      YI=YI/(R1D2+SQRT(ABS(R1D2SQ+COSD2*YI)))
      YN15=YN15/(R1C2+SQRT(ABS(R1D2SQ+COSD2*YN15)))
 1107 R25=R(1)+YI*CSALFA
      RN15=R(1)+YN15*CSALFA
      YE=Y(NP3)-YN15
      RETURN
C     ------------------------------------------  CSALFA EQ ZERO
 1110 DO 1111 I=2,NP3
      Y(I)=Y(I)/R(1)
 1111 R(I)=R(1)
      YI=YI/R(1)
      YN15=YN15/R(1)
      R25=R(1)
      RN15=R(1)
      YE=Y(NP3)-YN15
      RETURN
C**************************************  S T R I D E 2  ****************
C     ------------------------------  PRELIMINARIES [illegible] COEFFICIENTS
 2000 EVAPI=0.
      DO 2660 I=2,NPZ
      HLPE(I)=0.
 2660 EVAPI=EVAPI+EVAP(I)
      PX=PEI/DX
      P08=.125*PX
      P04=P08+P09
      G=PMI-PME
      APMI=ABS(PMI)
      APME=ABS(PME)
      G04=.25*G
      G=G+EVAPI
      PG=PX*G
      PG08=.125*PG
      PG04=PG08+PG08
      RPID2=.5*RPI
      DO 2004 I=2,NPZ
      DO 2670 K=2,NPZ
      IF (K-I) 2671,2672,2672
 2671 HLPE(K)=HLPE(K)-.25*EVAP(I)*ONMOM(K)
      GO TO 2670
 2672 HLPE(K)=HLPE(K)+.25*EVAP(I)*(2.-OMPOM(K))
 2670 CONTINUE
      PBOM(I)=PX*BOM(I)
 2004 PGCM(I)=PG04*OMD(I)
      P4OPP=PC4*BOP(2)
C     ------------------------------------------  GRID POINT 2
C------------------------------------------  TAUI, BPI, T1
      IF(KIN.NE.1) GO TO 2001
      CALL WF(0,1,BPI,T1,TAUI)
      GO TO 2002
 2001 T1=0.
      IF(NRAD.EQ.0) BPI=.33333+.66667*RU(1)/RU(2)
      IF(NRAD.EQ.1) BPI=(R(1)*(5.*RU(1)+RU(2))+3.*R25*
     1                     (RU(1)+RU(2)))/6./(R(1)+R25)/RU(2)
 2002 DO 2700 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 2700
      IF (KIN.NE.1) GO TO 2705
      CALL WF (J,1,FDIFI(J),TIFF(J),SI(J))
      IF (INDI(J).EQ.2) GO TO 2700
      AJI(J)=CI(J)*(F(J,1)-.5*(F(J,2)+F(J,3))-FDIFI(J))
      GO TO 2700
 2705 TIFF(J)=0.
      FDIFI(J)=0.
 2700 CONTINUE
C     ------------------------------------------  GRID POINT NPZ
C------------------------------------------  TAUE, BPE, TNP3
 2304 IF(KEX.NE.1) GO TO 2003
      CALL WF(3,NP3,BPE,TNP3,TAUE)
```

```
      GO TO 2310
 2003 TMP3=0.
      IF(KRAD.EQ.0) BPE=.33333+.66667*RU(NP3)/RU(NP1)
      IF(KRAD.EQ.1) BPE=(P(NP3)*(5.*RU(NP3)+RU(NP1))+3.*RN15*
     1                 (RU(NP3)+RU(NP1)))/6./(P(NP3)+ RN15)/RU(NP1)
 2310 DO 2720 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 2720
      IF (KEX.NE.1) GO TO 2730
      CALL WF(J,NP3,FDIFE(J),TMP3FF(J),GE(J))
      IF (IMODE(J).EQ.2) GO TO 2720
      AJE(J)=GE(J)*(.5*(F(J,NP2)+F(J,NP1))+FDIFE(J)-F(J,NP3))
      GO TO 2720
 2730 TMP3FF(J)=0.
      FDIFE(J)=0.
 2720 CONTINUE
      RETURN
C*************************************  S T R I D E 3  ****************
 3000 CALL SOURCE(0)
C ------------------------  BOUNDARY COEFFICIENTS FOR VELOCITY
C  ---------  GRID POINT 2 COEFFICIENTS  --------------
      AKASU=KASU
      HLP=RMID2-GD4*OMPOM(2)+HLPF(2)
      AMLP=ABS(HLP)
      THLP=HLP+HLP
      THLPT(2)=THLP
      TP=EM U(2)
      TTP=TP+AMLP+ABS(TP-AMLP)
      A(2)=TTP-THLP-T1-PGOM(2)*AKASU
      B(2)=2.*T1+BMI+ARMI
      C(2)=P4OMP*(3.*U(2)+U(3))+2.*SU(2)
      IF (KASU.EQ.0) C(2)=4.*P4OMP*U(2)+2.*SU(2)
      D(2)=A(2)+B(2)+PBOM(2)-2.*SD(2)
C  --------  GRID POINT NP2 COEFFICIENTS  ------------
      HLM=RMID2-GD4*OMPOM(NP1)+HLPE(NP1)
      AMLM=ABS(HLM)
      THLP=HLM+HLM
      THLPT(NP2)=THLP
      TM=EM U(NP1)
      TTM=TM+AMLM+ABS(TM-AMLM)
      P4OMM=PD4*POP(NP2)
      A(NP2)=2.*TMP3-BME+ARME
      B(NP2)=TTM+THLM-TMP3-PGOM(NP1)*AKASU
      C(NP2)=P4OMM*(3.*U(NP2)+U(NP1))+2.*SU(NP2)
      IF (KASU.EQ.0) C(NP2)=4.*P4OMM*OM(NP2)+2.*SU(NP2)
      D(NP2)=A(NP2)+B(NP2)+PBOM(NP2)-2.*SD(NP2)
C  --------  MID-STREAM COEFFICIENTS  ----------
      DO 3005 I=3,NP1
      THLM=THLP
      HLP=RMID2-GD4*OMPOP(I)+HLPF(I)
      THLP=HLP+HLP
      THLPT(I)=THLP
      AMLP=ABS(HLP)
      AMLPT(I)=AMLP
      TTM=TTP
      TP=EP U(I)
      TTP=TP+AMLP+ABS(TP-AMLP)
      A(I)=TTP-THLP-PGOP(I)*AKASU
      B(I)=TTM+THLM-PGOM(I-1)*AKASU
      C(I)=PD4*(BOPT3(I)*U(I)+OPD(I)*U(I+1)+OMD(I-1)*U(I-1))+2.*SU(I)
      IF (KASU.EQ.0) C(I)=4.*PD4*ROP(I)*U(I)+2.*SU(I)
      D(I)=A(I)+B(I)+PBOP(I)-2.*SD(I)
 3005 CONTINUE
      GO TO (3021,3020), NOVEL
 3020 IF(ITEST) 3900,3905,3905
 3900 WRITE(6,3901) (A(I),I=2,NP2)
      WRITE(6,3902) (B(I),I=2,NP2)
      WRITE(6,3903) (C(I),I=2,NP2)
      WRITE(6,3904) (D(I),I=2,NP2)
 3901 FORMAT(7H  A(I) ,1P11E11.3/(7X,11E11.3))
 3902 FORMAT(7H  B(I) ,1P11E11.3/(7X,11E11.3))
 3903 FORMAT(7H  C(I) ,1P11E11.3/(7X,11E11.3))
 3904 FORMAT(7H  D(I) ,1P11E11.3/(7X,11E11.3))
 3905 CONTINUE
C--------------------------                    ----------------------
      IF(KIN.EQ.2.AND.RU(I).NE.0.) U(I)=U(I)-DPDY(I)*DX/RU(I)
      IF(KEX.EQ.2.AND.RU(NP3).NE.0.) U(NP3)=U(NP3)-DPDX(NP3)*DX/RU(NP3)
C--------------------------  SOLVE FOR DOWNSTREAM U'S  --------------
```

```
      B(2)=(B(2)*J(1)+C(2))/D(2)
      A(2)=A(2)/D(2)
      DO 3040 I=3,NP2
      T=D(I)-B(I)*A(I-1)
      A(I)=A(I)/T
 3040 B(I)=(B(I)*B(I-1)+C(I))/T
      DO 3050 IDASH=2,NP2
      I=N+4-IDASH
      U(I)=A(I)*U(I+1)+B(I)
C     ------------------------------------ TEST FOR NEGATIVE U'S
C/IUTRAP=0,NO ACTION/ .GT.0,SET TO 1.E-30/ .GT.1,IFIN=-1/ .GT.2,ITEST=1/
      IF(IUTRAP.EQ.0.OR.I.EQ.2.OR.I.EQ.NP2) GO TO 3050
      IF(U(I)) 3046,3046,3050
 3046 J=ISTEP+1
      WRITE(6,3047) U(I),I,J
 3047 FORMAT(25H ********** U (LE ZERO) =,1PE10.3,5H AT I=,I3,
     1 8H, ISTEP=,I6,34H, SET U TO 1.E-30 ******** STRIDE3)
      U(I)=1.E-30
      IFIN=-IUTRAP/2
      ITEST=IUTRAP/3
 3050 CONTINUE
C     ------------------------------------------------
      IF(KIN.EQ.3) U(1)=.5*(U(2)+U(3))
      IF(KEX.EQ.3)U(NP3)=.5*(U(NP1)+U(NP2))
 3021 IF (ITEST) 3011,3014,3011
 3011 WRITE(6,3012) (U(I),I=1,NP3)
 3012 FORMAT(3H U ,5X,1P11E11.3/(9X,11E11.3))
C     ------------------------------------------------
C     ----------------   SOLVE FOR DOWN STREAM F'S   ------------------
 3014 DO 3321 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 3321
      AKAS=FLOAT(IKAS(J))
C     ------   COMPUTE SOURCE TERMS   ---------
      CALL SOURCE(J)
C     -------   GRID POINT 2   --------
      TP=EM U(2)
      TPF2=TP/PREF(J)
      THLP=THLPT(2)
      AHLP=.5*ABS(THLP)
      TTPF(J)=TPF2+AHLP+ABS(TPF2-AHLP)
      TIF=TIFF(J)
      IF (KIN.NE.1) GO TO 2302
      IF(INDI(J).EQ.2) GO TO 2303
CC    -----------   EDGE VALUE SPECIFIED   -----------
 2302 A(2)=TTPF(J)-THLP-TIF-(PGOM(2)-.5*SD(2))*AKAS
      B(2)=2.*TIF*RPI+ARPI
      C(2)=A(2)+B(2)+PBCP(2)-2.*SD(2)
      IF (J.NE.JVT) GO TO 510
      PP=.5*(P(2)+P(3))
      ATP=2.*(PP/R(3))**2
      AT1=(R(1)/PP)**2
      DTP=2.*(RP/(.75*R(2)+.25*R(3)))**2
      A(2)=TTPF(J)*ATP-THLP-TIF*AT1-(PGOM(2)-.5*SD(2))*AKAS
      TT=3.*PGOM(2)-1.5*SD(2)
      IF (IKAS(J).EQ.0) TT=4.*PGOM(2)-2.*SD(2)
      D(2)=TTPF(J)*DTP+TIF+THLP+TT
  510 T=-TIF*FDIFI(J)
      GO TO 2305
C     ----------------   EDGE FLUX SPECIFIED   ------------
 2303 A(2)=TTPF(J)-THLP-(PGOM(2)-.5*SD(2))*AKAS
      B(2)=0.
      D(2)=A(2)+PBOM(2)-2.*SD(2)+2*I*2.
      T=P*I*F(J,1)+ZJI(J)*R(1)
 2305 TT=3.*F(J,2)+F(J,3)
      IF (IKAS(J).EQ.0) TT=6.*F(J,2)
      C(2)=P4OPP*TT+2.*(T+SU(2))
 2306 CONTINUE
C     -----------   GRID POINT NP2   --------
      TM=EM U(NP1)
      TMF=TM/PREF(J)
      THLM=THLPT(NP2)
      AHLM=.5*ABS(THLM)
      TTMF=TMF+AHLM+ABS(TMF-AHLM)
      TMP3F=TMP3FF(J)
      IF (KEX.NE.1) GO TO 2312
      IF(INDE(J).EQ.2) GO TO 2312
C     ---------------   EDGE VALUE SPECIFIED   --------
```

```
 2312 A(NP2)=2.*TMP3F-RME+ARME
      B(NP2)=TTMF+THLM-TMP3F-(PGOM(NP1)-.5*SD(NP2))*AKAS
      D(NP2)=A(NP2)+B(NP2)+PBOM(NP2)-2.*SD(NP2)
      IF (J.NE.JVT) GO TO 520
      RM=.5*(R(NP2)+R(NP1))
      BTM=2.*(RM/R(NP1))**2
      BTMP3=(R(NP3)/RM)**2
      DTM=2.*(RM/(.75*R(NP2)+.25*R(NP1)))**2
      B(NP2)=TTMF*BTM+THLM-TMP3F*BTMP3-(PGOM(NP1)-.5*SD(NP2))*AKAS
      TT=3.*PGOM(NP1)-1.5*SD(NP2)
      IF (IKAS(J).EQ.0) TT=4.*PGOM(NP1)-2.*SD(NP2)
      D(NP2)=TTMF*DTM+TMP3F-THLM*TT
  520 T=-TMP3F*FDIFE(J)
      GO TO 2315
C ----------- EDGE FLUX SPECIFIED ---------
 2313 A(NP2)=0.
      B(NP2)=TTMF+THLM-(PGOM(NP1)-.5*SD(NP2))*AKAS
      D(NP2)=B(NP2)+PBOM(NP2)-2.*SD(NP2)-RME*2.
      T=-RME*F(J,NP3)-AJE(J)*R(NP3)
 2315 TT=3.*F(J,NP2)+F(J,NP1)
      IF (IKAS(J).EQ.0) TT=4.*F(J,NP2)
      C(NP2)=P4OMM*TT+2.*(T+SU(NP2))
 2320 CONTINUE
C -------- MID-STREAM COEFFICIENTS ---------
      DO 3002 I=3,NP1
      TTMF=TTPF(J)
      TPF=EM U(I)/PREF(J)
      TTPF(J)=TPF+AHLPT(I)+ABS(TPF-AHLPT(I))
      IF (J.EQ.JVT) GO TO 3015
      A(I)=TTPF(J)-THLPT(I)-PGOM(I)*AKAS
      B(I)=TTMF+THLPT(I-1)-PGOM(I-1)*AKAS
      D(I)=A(I)+B(I)+PBOM(I)-2.*SD(I)
      GO TO 2999
C ---------------
 3015 RP=.5*(R(I)+R(I+1))
      RM=.5*(R(I)+R(I-1))
      RMM=R(I-1)
      IF (I.EQ.3) RMM=.75*R(2)+.25*R(3)
      RPP=R(I+1)
      IF (I.EQ.NP1) RPP=.75*R(NP2)+.25*R(NP1)
      ATP=2.*(RP/RPP)**2
      BTP=2.*(RM/RMM)**2
      DTP=2.*(RP/R(I))**2
      DTM=2.*(RM/R(I))**2
      A(I)=TTPF(J)*ATP-THLPT(I)-PGOM(I)*AKAS
      B(I)=TTMF*BTM+THLPT(I-1)-PGOM(I-1)*AKAS
      TT=PGD4*BOMT3(I)
      IF (IKAS(J).EQ.0) TT=4.*PGOM*DP(I)
      D(I)=TTPF(J)*DTP+TTMF*DTM+THLPT(I)-THLPT(I-1)+TT-2.*SD(I)
 2999 TT=BOMT3(I)*F(J,I)+OMD(I)*F(J,I+1)+OMD(I-1)*F(J,I-1)
      IF (IKAS(J).EQ.0) TT=4.*DOM(I)*F(J,I)
 3002 C(I)=PD4*TT+2.*SU(I)
      IF(ITEST) 3906,3907,3906
 3906 WRITE(6,3901) (A(I),I=2,NP2)
      WRITE(6,3902) (B(I),I=2,NP2)
      WRITE(6,3903) (C(I),I=2,NP2)
      WRITE(6,3904) (D(I),I=2,NP2)
 3907 CONTINUE
C ----------------------------------------
      B(2)=(B(2)*F(J,1)+C(2))/D(2)
      A(2)=A(2)/D(2)
      DO 3148 I=3,NP2
      T=D(I)-B(I)*A(I-1)
      A(I)=A(I)/T
 3148 B(I)=(B(I)*B(I-1)+C(I))/T
      DO 3150 IDASH=2,NP2
      I=N+4-IDASH
 3150 F(J,I)=A(I)*F(J,I+1)+B(I)
C ------------------------- ADJUST F(J,1) AND F(J,NP3) -----------
      GO TO (3210,3220,3230),KIN
 3210 IF(INDI(J).EQ.2) F(J,1)=FDIFI(J)+.5*(F(J,2)+F(J,3))+AJI(J)/GI(J)
      GO TO 3220
 3230 F(J,1)=.5*(F(J,2)+F(J,3))
 3220 GO TO (3310,3320,3330),KEX
 3310 IF(INDE(J).EQ.2) F(J,NP3)=FDIFE(J)+.5*(F(J,NP2)+
     1                            F(J,NP1))-AJE(J)/GE(J)
      GO TO 3320
```

```
 3330 F(J,MP3)=.5*(F(J,MP1)+F(J,MP2))
 3320 IF(ITEST) 3322,3321,3322
 3322 WRITE(6,3323) J,(F(J,I),I=1,MP3)
 3323 FORMAT(5H F, J=,I3,1P11E11.3/(9X,11E11.3))
 3321 CONTINUE
 3040 XU=XD
      PSII=PSII-RMI*DX
      PSIE=PSIE-RME*DX
      PSIE=PSIE+EVAPI*DX
      PEI=PSIE-PSII
      IF (ISTEP.GE.IOUT) GO TO 3710
      IF (KEX.NE.2) GO TO 3700
      SUM2=SUM2-RME*DX
      GO TO 3710
 3700 IF (KEX.NE.1) GO TO 3710
      SUM4=SUM4-RME*DX
 3710 IF (ISTEP.GE.IEND) GO TO 3750
      IF (KIN.NE.2) GO TO 3740
      SUM1=SUM1+RMI*DX
      GO TO 3750
 3740 IF (KIN.NE.1) GO TO 3750
      SUM3=SUM3+RMI*DX
 3750 CONTINUE
      ISTEP=ISTEP+1
      RETURN
C************************** S T A R T E A ***************/*************
 4000 CONTINUE
      M2=M/2
      MP1=M+1
      MP2=M+2
      MP3=M+3
      DP(1)=0.
      DP(MP3)=1.
      ISTEP=0
      IEND=10000
      IAX=10000
      IOUT=10000
      DX=1.E-30
      IFIN=0
      KIN=1
      KEX=1
      RETURN
 7010 FORMAT(1H ,1P11E11.3)
      END
```

CARD NO.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
217	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
376	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
382	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.

```
      SUBROUTINE WF(J,I1,OUT1,OUT2,OUT3)
      COMMON/COMA/A(43),AJE(16),AJI(16),B(43),C(43),CSALFA,D(43),
     1 DPDX(43),DX,EMU(43),F(16,43),FS(3,43),IAX,IEND,IFIN,INDE(16),
     2 INDI(16),IOUT,ISTEP,ITEST,IUTRAP,JS,JSW,JV,JY,KEX,KIN,KRAD,N,
     3 NDZ,NF,NOVEL,NP1,NP2,NP3,OM(43),OMD(43),P(43),PEI,PR(16),
     4 PREF(16),PSIE,PSII,R(43),RHO(43),RU(43),RME,RMI,SD(43),SU(43),
     5 TAUE,TAUI,U(43),XD,XU,Y(43),YE,YI,PSWRL(43),RDY(43),ISOLVE(16),
     6 US(43),AMU(43),SUM1,SUM2,SUM3,SUM4,PISSCH,FDIFI(16),FDIFE(16),
     7 GE(16),GI(15),JLOC(12),W(12),JH,JFU,JCO2,JCO,JOX,JH2O,JOH,JO,JHS,
     8 JH2,JN,JNO,JN2,JVI,JD,JF,JT,JRV,NSP,NSPM,ARSNP,SCATR,SOP(20C),
     9 EMI,SIGMA,CP,JFUOX,IFLUX,EVAP(43),TFUEL,HFU
      COMMON/COMB/AK,ALNG,EWALL,FR,H,HFU,INFRT,MASSTP,MODEL,PRESS,
     1 UBAR,UFAC,C1,C2,CD,C2VT,AKFAC,ALFAC,ARCONI,ARCON2,PREXP1,CD75,
     2 PREXP2,CR1,CR2,PODER,ROJCP,RATIO1,RATIO2,RATIO3,RATIO4,RATIO5,
     3 CX,HY,DXOLD,WFU,WCO2,WCO,WOX,WH2O,WOH,WO,WH,
     4 WH2,WN,WNO,WN2
C/-------- SUBROUTINE FOR PROGRAM GENMIX 6A
C/----------------- D.B.SPALDING, IMPERIAL COLLEGE, 1972 ----------------
C
C     EFFECTS OF PRESSURE GRADIENT AND MASS TRANSFER ARE INCLUDED
C     EFFECTS OF RADIUS VARIATION ARE NEGLECTED
C     FOR VELOCITY,       OUT1=RP,     OUT2=T,   OUT3=TAU
C     FOR F'S,            OUT1=FIDIF,  OUT2=T,   OUT3=G
C
      DATA SHALF/.04/, BPLAST/.9/
      INT=I/I1
      I2=I1-1+2*INT
      I3=I1-2+4*INT
      I25=I3-INT
      IF(J) 100,1C0,200
C ---------------------------------------------  VELOCITY
  100 UREF=.5*(U(I2)+U(I3))
      RHOREF=.5*RHO(I1)+.25*(RHO(I2)+RHO(I3))
      RUREF=RHOREF*UREF
      RREF=.5*(R(I2)+R(I3))
      VREF=EMU(I1)
      YREF=YI+(YE-YI)*OM(I1)
      RE=UREF*RHOREF*YREF/VREF
      RRUREF=RREF*RUREF
      AM=(RMI-(RME+RMI)*OM(I1))/RRUREF
      EF=YREF*DPDX(I1)/RUREF/UREF
      IF(MODEL.EQ.1) GO TO 110
      IF(RE.LT.132.25) GO TC 110
C------------------------------------------------EXTENDED LOG LAW
      EP=RE*EWALL
      NIT=0
  101 SHALFI=SHALF
      S=SHALF**2
      SLOC=S+AM+EF
      IF(SLOC.GT.0.) GC TO 104
      SLOC=1.E-30
      SHALF=SQRT(ABS(AM+EF))
  104 BEE=SQRT(SLOC)/AK
      ARG=ER*(SHALF+(AP/(1.+BEE)+.5*EF)/SHALF)
      IF(ARG.GT.11.5*EWALL) GO TO 106
      GO TO 110
  106 SHALF=AK/ALOG(ARG)
      IF(ABS(SHALF-SHALFI).LT..0001.OR.NIT.GT.10) GO TO 102
      NIT=NIT+1
      GO TO 101
  102 S=SHALF**2
      SAV=.5*(SHALF**2+SLOC)
      OUT1=1./(1.+BEE)
      EP U(I25)=.25*RHOREF*RREF*ABS(U(I3)-U(I2))*(AK/OUT1)**2
      GO TO 103
C ---------------------------------------------  LAMINAR FLOW
  110 APRE=AM*RE
      FRE=EF*RE
      IF(ABS(AMRE).LT..01) GO TO 111
      APRE=AMAX1(-50.,AMIN1(50.,AMRE))
      EXPMRE=EXP(APRE)
      STORE=EXPMRE-1.-AMRE
      AMRESQ=AMRE*AMRE
      SRE=AMRE*(1.-STORE*FRE/AMRESQ)/(EXPMRE-1.)
      OUT1=SRE*STORE/AMRESQ+FRE*(STORE-.5*AMRESQ)/(AMRESQ*AMRE)
      GO TO 112
  111 SRE=(2.-FRE*(1.+AMRE/3.))/(2.+AMRE)
```

```
      OUT1=SPE*(.5+AMRE/6.)+F*F*(.16667+AMRE/24.)
  112 IF(SRE.GT.1.E-30) GO TO 113
      SPE=1.E-30
      OUT1=.33333
  113 S=SPE/PE
      F= U(125)=VREF*RREF/ABS(Y(I3)-Y(I2))
  103 OUT2=S*RRUREF
      OUT3=OUT2*UREF/R(I1)
C     ----------- UNDER-RELAX OUT1.
      OUT1=.1*OUT1+.9*BPLAST
      BPLAST=OUT1
      RETURN
C------------------- STAGNATION ENTHALPY, FIEL. OX-FU/OXDFU
  200 IF(RE.LT.132.25) GO TO 210
      IF(MODEL.EQ.1) GO TO 210
      IF (ARG.LE.11.5*EWALL) GO TO 210
      PRRAT=PR(J)/PREF(J)
      PJAY=9.*(PRRAT-1.)/PRRAT**.25
      S=SAV/PREF(J)/(1.+AMAX1(-.99999,PJAY*SQRT(ABS(SAV))))
      OUT1=0.
      IF (J.EQ.JM) OUT1=(H-1.)*.5*UREF**2
      OUT2=S*RRUREF
      IF (J.EQ.JK) OUT2=0.
      OUT3=OUT2/R(I1)
      RETURN
  210 IF(ABS(AMRE).LT..01) GO TO 211
      S=AM/(EXP(PR(J)*AMRE)-1.)
      GO TO 212
  211 S=1./PR(J)/RE/(1.+.5*PR(J)*AMRE)
  212 OUT1=0.
      IF (J.EQ.JM) OUT1=(PR(J)-1.)*.5*UREF**2
      OUT2=S*RRUREF
      IF (J.EQ.JK) OUT2=0.
      OUT3=OUT2/R(I1)
      RETURN
      END
```

```
      SUBROUTINE PLOTS (X,IDIM,IMAX,XAXIS,Y,JDIM,JMAX,YAXES,SYMBOL)
C*****14.9.72*******************************************************
C                                                                  *
C   SUBROUTINE FOR PLOTTING J CURVES OF Y(J,I) AGAINST X(I).
C                                                                  *
C   X AND Y ARE ASSUMED TO BE IN ANY RANGE EXCEPT THAT NEGATIVE VALUES *
C    ARE PLOTTED AS ZERO.                                          *
C   X AND Y ARE SCALED TO THE RANGE 0. TO 1. BY DIVISION BY THE MAXIMA, *
C    WHICH ARE ALSO PRINTED.                                       *
C   IDIM IS THE VARIABLE DIMENSION FOR X.                          *
C   IMAX IS THE NUMBER OF X VALUES.                                *
C   XAXIS STORES THE NAME OF THE X-AXIS.                           *
C   JDIM IS THE VARIABLE DIMENSION FOR Y.                          *
C   JMAX IS THE NUMBER OF CURVES TO BE PLOTTED, (UP TO 10).        *
C   THE ARRAY YAXES(J) STORES THE NAMES OF THE CURVES.             *
C   THE ARRAY SYMBOL(J) STORES THE SINGLE CHARACTERS USED FOR PLOTTING. *
C                                                                  *
C*******************************************************************
      DIMENSION X(IDIM),Y(JDIM,IDIM),YAXES(JDIM,2),SYMBOL(JDIM),
     1 A(101),YMAX(10)
      DATA  DOT,CROSS,BLANK/1H.,1H+,1H /
C*****  SCALING X ARRAY TO THE RANGE 0 TO 50
      XMAX=1.E-30
      DO 1 I=1,IMAX
    1 IF(X(I).GT.XMAX) XMAX=X(I)
      DO 2 I=1,IMAX
      X(I)=X(I)/XMAX*50.
    2 IF(X(I).LT.0.) X(I)=0.
C*****  SCALING Y ARRAY TO THE RANGE 0 TO 100
      DO 3 J=1,JMAX
      YMAX(J)=1.E-30
      DO 4 I=1,IMAX
    4 IF(Y(J,I).GT.YMAX(J)) YMAX(J)=Y(J,I)
      DO 3 I=1,IMAX
      Y(J,I)=Y(J,I)/YMAX(J)*100.
    3 IF(Y(J,I).LT.0.) Y(J,I)=0.
C*****  IDENTIFYING THE VARIOUS CURVES TO BE PLOTTED
      WRITE(6,103) XAXIS,XMAX
      WRITE(6,100)((YAXES(I,J),J=1,2),I=1,JMAX)
      WRITE(6,106) (SYMBOL(I),I=1,JMAX)
      WRITE(6,102) (YMAX(I),I=1,JMAX)
      DO 5 I=1,11
    5 A(I)=0.1*FLOAT(I-1)
      WRITE(6,101) (A(I),I=1,11)
C*****  MAIN LOOP.  EACH PASS PRODUCES AN X-CONSTANT LINE.
      DO 40 I=1,51
      IF(I.EQ.1.OR.I.EQ.51) GO TO 32
      GO TO 33
C*****  ALLOCATE . OR + AS MARKED ON THE Y-AXIS
   32 DO 30 K=1,101
   30 A(K)=DOT
      DO 31 K=11,101,10
   31 A(K)=CROSS
C*****  ALLOCATE . OR + MARK ON THE X-AXIS, ALSO THE APPROPRIATE X VALUE
   33 A(1)=DOT
      A(101)=DOT
      K=I-1
   46 K=K-5
      IF(K)48,47,46
   47 A(1)=CROSS
      A(101)=CROSS
   48 XL=0.02*FLOAT(I-1)
C*****  CHECK IF ANY Y( X(I) ) VALUE LIES ON THIS X-CONSTANT LINE
C*****  IF YES GO TO 41, OTHERWISE GO TO 42
      DO 43 K=1,IMAX
      IF(IFIX(X(K)+1.5)-I) 43,41,43
C*****  LOCATE  Y(  X(I)  )
   41 DO 44 J=1,JMAX
      NY=Y(J,K)+1.5
      A(NY)=SYMBOL(J)
   44 CONTINUE
      GO TO 42
   43 CONTINUE
C*****  PRINT X-CONSTANT LINE
   42 WRITE(6,105) XL,(A(K),K=1,101),XL
C*****  PUTTING BLANKS INTO X-CONSTANT LINE
      DO 49 K=1,101
```

```
   49 A(K)=BLANK                                                        PL   79
   40 CONTINUE                                                          PL   80
      DO 50 I=1,11                                                      PL   81
   50 A(I)=.1*FLOAT(I-1)                                                PL   82
      WRITE(6,104) (A(I),I=1,11)                                        PL   83
      RETURN                                                            PL   84
  100 FORMAT(11H Y-AXES ARE,5X,10(1X,A6,A4))                            PL   85
  101 FORMAT(1H0,2X,11F10.1)                                            PL   86
  102 FORMAT(15H MAXIMUM VALUES,1P10E11.3)                              PL   87
  103 FORMAT(11H0X-AXIS IS ,A8,17H ,MAXIMUM VALUE =,1PE10.3)            PL   88
  104 FORMAT (3X,11F10.1)                                               PL   89
  105 FORMAT(2H X,F6.2,3X,101A1,F6.2)                                   PL   90
  106 FORMAT(7H SYMBOL,11X,10(1X,A10))                                  PL   91
      END                                                               PL   92
```

APPENDIX E

LISTING OF TRANSITION MIXING MODEL

```
PROGRAM MAIN        73/74   OPT=0 TRACE                FTN 4.6+439        08/24/79  10.30.04        PAGE    1

      PROGRAM MAIN (INPUT,OUTPUT,TAPE5=INPUT,TAPE?=OUTPUT)               MA       2
C                                                                        MA       3
C     ****************************************************************** MA       4
C     ****************************************************************** MA       5
C     ***************** COMBUSTOR DESIGN CRITERIA ********************** MA       6
C     TRANSITION MIXING MODEL,                                           MA       7
C                                                                        MA       8
C                                                                        MA       9
C     ------------------------------------------------------------------ MA      10
CHAPTER0000000000000000000  PRELIMINARIES  000000000000000000000000000 MA      11
C     ----------------------- DIMENSIONS AND COMMON BLOCKS.              MA      12
      COMMON/COMA/A(43),AJE(7),AJI(7),B(43),C(43),CSALFA,D(43),DPDX(43), COMA     2
     1 DX,EMU(43),F(7,43),FS(5,43),IAX,IEND,IFIN,INDE(7),INDI(7),IOUT,   COMA     3
     2 ISTEP,ITEST,IUTRAP,JS,JSW,JV,JT,KEX,KIN,KRAD,M,NO2,NF,NOVEL,NP1,  COMA     4
     3 NP2,NP3,OM(43),OMD(43),P(43),PEI,PR(7),PREF(7),PSIE,PSII,R(43),   COMA     5
     4 RHO(43),RME,RMI,RU(43),SD(43),SU(43),TAUE,TAUI,U(43),XD,XU,       COMA     6
     5 Y(43),YE,YI,PSWRL(43),RDY(43),ISOLVE(7),US(43),AMU(43),           COMA     7
     5 DZ(43),DZOLD(43),ZUI,ZUE,ZDI,ZDE,DPDOX(43),                       COMA     8
     6 JH,JFU,JFUOX,JCO,JVT,JK,JD,JOX,JT,JN2,JH2O,JCO2                   COMA     9
      COMMON/COMB/AK,ALMG,EWALL,FR,H,HFU,INERT,MASSTR,MODEL,PRESS,       COMB     2
     1 UBAR,UFAC,C1,C2,CD,C2VT,AKFAC,ALFAC,ARCON1,ARCON2,PREXP1,CO7>,   COMB     3
     2 PREXP2,CR1,CR2,MODER,MODCP,RATIO1,RATIO2,RATIO3,RATIO4            COMB     4
      COMMON/COMC/ARE(40),ZRE(40),XRE(40),ARI(40),ZRI(40),XRI(40),       COMC     2
     1 NBP,NRCVI,NRCVE,ZSI(30),ZSE(30),RCVI(30),RCVE(30)                 COMC     3
      DIMENSION TITLE(24),OUT(43),LAB(2)                                 MA      16
      DIMENSION XPLOT(43),YPLOT(10,43),YAXES(10,2),SYMBOL(10)            MA      17
      DIMENSION FLUX(7),DFI(7),DFE(7),AJIO(7),AJEO(7)                    MA      18
      DIMENSION YIN(40),UIN(40),VTIN(40),TIN(40),MFUIN(40),MCOIN(40)     MA      19
      DIMENSION TKIN(40),TLIN(40),MCO2IN(40)                             MA      20
      DIMENSION IPLOT(12),IPRNT(12),SYM(12),LAB1(12),LAB2(12)            MA      21
      REAL MFUIN,MCOIN,MCO2IN,LAB,LAB1,LAB2                              MA      22
      NAMELIST/INPUT/IUTRAP,ULIM,PEILIM,AFAC,AEXDLM,POWER,NOVEL,         MA      23
     1 ARCON1,PREXP1,CR1,ARCON2,PREXP2,CR2,CP,IDPDX,C1,C2,CD,            MA      24
     2 C2VT,AKFAC,ALFAC,PREF,CX,HY,HFU,MODER,ITHIN,KREAD                 MA      25
      DATA JH,JFU,JFUOX,JCO,JVT,JK,JD/1,2,3,4,5,6,7/                     MA      26
      DATA JOX,JT,JN2,JH2O,JCO2/1,2,3,4,5/                               MA      27
      DATA IPLOT/0,1,0,1,1,0,0,1,1,0,0,0/                                MA      28
      DATA SYM/1HE,1HF,1HP,1HC,1HV,1HK,1HD,1HO,1HT,1HN,1HM,1H3/          MA      29
      DATA LAB1/6HENTH  ,6HFUEL  ,6HPHI   ,6HCO    ,6HVT    ,6HKE    ,   MA      30
     1 6HLEN SC,6HOXYGEN,6HTEMP  ,6HN2    ,6HH2O   ,6HCO2   /            MA      31
      DATA LAB2/2H  ,2H  ,2H  ,2H  ,2H  ,2H  ,2H  ,2H  ,2H  ,2H  ,       MA      32
     1      2H  ,2H  /                                                   MA      33
      DATA WOX,WCO2,WCO,WH2O,WN2/32.,44.,28.,18.,28./                    MA      34
C                                                                        MA      35
      READ(5,1) TITLE                                                    MA      36
    1 FORMAT(12A6)                                                       MA      37
C                                                                        MA      38
C     ------------------------------------------------------------------ MA      39
CHAPTER1111111111111111111  PARAMETERS AND CONTROL INDICES  1111111111111 MA      40
      READ (5,2) N,KRAD,MASSTR,ISWRL,MODEL,INERT,IFLUX,ITEMP             MA      41
    2 FORMAT (8(I2,8X))                                                  MA      42
      READ (5,3) NSTAT,NPROF,NPLOT,ITEST,LASTEP                          MA      43
    3 FORMAT (8(I5,5X))                                                  MA      44
      IUTRA?=2                                                           MA      45
      ULIM=.05                                                           MA      46
      PEILIM=.01                                                         MA      47
      AFAC=.2                                                            MA      48
      AEXDLM=.02                                                         MA      49
      IDPDX=1                                                            MA      50
      H=.9                                                               MA      51
      AK=.435                                                            MA      52
      ALMG=.?9                                                           MA      53
      FP=.033                                                            MA      54
      UFAC=.01                                                           MA      55
      NOVEL=2                                                            MA      56
      ITHIN=1                                                            MA      57
      KREAD=0                                                            MA      58
C                                                                        MA      59
C     ------------------------------------------------------------------ MA      60
CHAPTER2222222222222222222222  GRID AND GEOMETRY  2222222222222222222 MA      61
      READ (5,4) ZUI,ZUE,ZULAST,FRA,ZEND,ZOUT,PRESS,POWER                MA      62
      READ (5,2) NBP,ICURV,NRCVI,NRCVE                                   MA      63
      READ (5,4) (ARI(I),XRI(I),I=1,NBP)                                 MA      64
      READ (5,4) (ARE(I),XRE(I),I=1,NBP)                                 MA      65
      IF (ICURV) 11,11,12                                                MA      66
   12 READ (5,4) (ZSI(I),RCVI(I),I=1,NRCVI)                              MA      67
      READ (5,4) (ZSE(I),RCVE(I),I=1,NRCVE)                              MA      68
```

```
   14 FORMAT (6E12.6)
C ------- CALCULATE Z-VALUES
   11 DO 15 I=2,NBP
      DELR=ARI(I)-ARI(I-1)
      DELX=XRI(I)-XRI(I-1)
      ZRI(I)=SQRT(DELR**2+DELX**2)
      DELR=ARE(I)-ARE(I-1)
      DELX=XRE(I)-XRE(I-1)
   15 ZRE(I)=SQRT(DELR**2+DELX**2)
      ZRI(1)=0.
      ZRE(1)=0.
      DO 16 I=2,NBP
      ZRI(I)=ZRI(I)+ZRI(I-1)
   16 ZRE(I)=ZRE(I)+ZRE(I-1)
      RI=TAB(ZUI,ZRI,ARI,NBP)
      RE=TAB(ZUE,ZRE,ARE,NBP)
      XI=TAB(ZUI,ZRI,XRI,NBP)
      XE=TAB(ZUE,ZRE,XRE,NBP)
      CSALFA=(RE-RI)/SQRT((RE-RI)**2+(XE-XI)**2)
      READ (5,4) RA,RB,RD
    4 FORMAT (8E10.4)
C     ----- R(1) ADJUSTMENT MADE JUST BEFORE CALL STRIDE(1).
C     ------------STRIDE4-----------STRIDE4-----------STRIDE4---------STRIDE4
      CALL STRIDE(4)
      IF (ZEND.EQ.0.) IEND=0
      IF (ZOUT.EQ.0.) IOUT=0
C     ---------------------- CHANGE IEND, IAX AND IOUT, IF NECESSARY.
      DO 20 I=2,NP2
   20 Y(I)=(FLOAT(I-2)/FLOAT(N))**POWER
C
C     ------------------------------------------------------------------------
CHAPTER3333333333333333333333333  DEPENDENT VARIABLES SELECTION  33333333
C
      ISOLVE(1)=ITEMP
      ISOLVE(2)=MASSTR
      ISOLVE(3)=MASSTR
      ISOLVE(4)=MASSTR
      ISOLVE(5)=ISWRL
      ISOLVE(6)=MODEL-1
      ISOLVE(7)=MODEL-1
      NF=7
      NFS=4
      IPRNT(JH)=0
      IPRNT(JFU)=MASSTR
      IPRNT(JFUOX)=MASSTR
      IPRNT(JCO)=MASSTR
      IPRNT(JVT)=ISWRL
      IPRNT(JK)=MODEL-1
      IPRNT(JD)=MODEL-1
      INDX=7
      IPRNT(JOX+INDX)=MASSTR
      IPRNT(JT+INDX)=ITEMP
      IPRNT(JN2+INDX)=0
      IPRNT(JH2O+INDX)=0
      IPRNT(JCO2+INDX)=0
C
C     ------------------------------------------------------------------------
CHAPTER4444444444444444444444444444  MATERIAL CONSTANTS  444444444444444
C                                        S.I. UNITS
      GASCON=8314.
      WMIX=28.04
      CP=1255.
      CI=1.0
      HY=4.
      HFU=4.E7
C     ---ARRCON IS ACTIVATION ENERGY DIVIDED BY UNIVERSAL GAS CONSTANT.
      PREXP1=5.E+15
      ARCON1=28500.
      CR1=6.0
      PREXP2=6.4E+8
      ARCON2=12500.
      CR2=6.0
      NODER=2
C
      DO 40 J=1,NF
      PR(J)=.7
      PREF(J)=.86
```

```
   40 IF (MODEL.EQ.1) PREF(J)=PR(J)
      PREF(JVT)=1.2
C  ------  TURBULENCE CONSTANTS       ------ ----
      C1=1.42
      C2=1.92
      CD=.09
      AKFAC=.03
      ALFAC=.02
      C2VT=0.36
      PREF(JK)=1.0
C  ----------      NAMELIST     -------
      READ (5,INPUT)
      PREF(JD)=AK**2/(C2-C1)/SQRT(CD)
      CD75=CD**.75
      GAMMA=CP/(CP-GASCON/WMIX)
      PDGSCN=PRESS*WMIX/GASCON
      WFU=12.*CX+HY
      RATIO1=WOX*(CX+HY/4.)/WFU
      RATIO2=.232
      RATIO3=WOX*0.5/WCO
      RATIO4=WCO*CX/WFU
C
C  ------------------------------------------------------------------
CHAPTER5555555555555555555555555555555555  INITIAL CONDITIONS  5555555555
      READ (5,4) UA,UG,VTA,VTD
      READ (5,4) F2A,F2D,TA,TD,TWALL
C
      F1A=CP*TA+.5*UA**2+HFU*F2A
      F1D=CP*TD+.5*UD**2+HFU*F2D
      F3A=F2A
      F3D=F2D
      READ (5,2) NIN
      READ (5,4) (YIN(I),I=1,NIN)
      READ (5,4) (UIN(I),I=1,NIN)
      READ (5,4) (VTIN(I),I=1,NIN)
      READ (5,4) (TIN(I),I=1,NIN)
      READ (5,4) (MFUIN(I),I=1,NIN)
      READ (5,4) (MCO2IN(I),I=1,NIN)
      READ (5,4) (MCOIN(I),I=1,NIN)
      IF (KREAD.EQ.0) GO TO 19
      READ (5,4) (TKIN(I),I=1,NIN)
      READ (5,4) (TLIN(I),I=1,NIN)
   19 CONTINUE
      DY=SQRT((RE-RI)**2+(XE-XI)**2)
      Y(1)=0.0
      Y(NP3)=1.0
      DO 55 I=1,NP3
   55 Y(I)=Y(I)*DY
C
      DO 400 I=1,NP3
      U(I)=TAB(Y(I),YIN,UIN,NIN)
      F(JFU,I)=TAB(Y(I),YIN,MFUIN,NIN)
      FS(JCO2,I)=TAB(Y(I),YIN,MCO2IN,NIN)
      F(JCO,I)=TAB(Y(I),YIN,MCOIN,NIN)
      F(JVT,I)=TAB(Y(I),YIN,VTIN,NIN)
      FS(JT,I)=TAB(Y(I),YIN,TIN,NIN)
      IF (KREAD.EQ.0) GO TO 400
      F(JK,I)=TAB(Y(I),YIN,TKIN,NIN)
      F(JD,I)=CD*F(JK,I)**1.5/(TAB(Y(I),YIN,TLIN,NIN)+1.E-20)
  400 CONTINUE
C
      DO 410 I=1,NP3
      DPDX(I)=0.0
      DZOLD(I)=0.
      R(I)=RI+Y(I)*CSALFA+1.E-30
      F(JH,I)=CP*FS(JT,I)+.5*U(I)*U(I)+HFU*F(JFU,I)
      FUB=(FS(JCO2,I)+WCO2*F(JCO,I)/WCO)*WFU/(WCO2*CX)
      F(JFUOX,I)=F(JFU,I)+FUB
      FS(JOX,I)=RATIO1*F(JFU,I)+RATIO3*F(JCO,I)+RATIO2-(RATIO2+RATIO1)
     I   *F(JFUOX,I)
      FS(JCO2,I)=WCO2*CX*FUB/WFU-WCO2*F(JCO,I)/WCO
      FS(JH2O,I)=HY*WH2O*FUB/WFU/2.
      FS(JN2,I)=1.-F(JFU,I)-FS(JCO2,I)-F(JCO,I)-FS(JOX,I)-FS(JH2O,I)
      IF (KREAD.EQ.1) GO TO 410
      F(JK,I)=AKFAC*U(I)*U(I)
      ALM=ALFAC*(Y(NP3)-Y(I))
      IF (IOUT.NE.0) ALM=AMIN1(ALM,ALFAC*Y(I))
```

```
      ALM=AMAX1(ALM,T(MP3)/100.)
      F(JO,I)=CD*F(JK,I)**1.5/ALM
  410 CONTINUE
C
      ALM=ALFAC*T(MP3)
      DO 52 I=1,MP3
      P(I)=PRESS
      PSWRL(I)=0.
      RII=R(I)
      IF (I.EQ.2) RII=.75*R(2)+.25*R(3)
      IF (I.EQ.MP2) RII=.75*R(MP2)+.25*R(MP1)
      F(JVT,I)=RII*F(JVT,I)
      WMIX=F(JFU,I)/WFU+FS(JCO2,I)/WCO2+F(JCO,I)/WCO+FS(JOX,I)/WOX+
     1      FS(JH2O,I)/WH2O+FS(JN2,I)/WN2
      RHO(I)=PRESS/FS(JT,I)/GASCON/WMIX
      IF (I.EQ.1) GO TO 52
      AFLO=.5*(R(I)**2-R(I-1)**2)
      IF (KRAD.EQ.0) AFLO=Y(I)-Y(I-1)
      DM(I)=.5*(RHO(I)*U(I)+RHO(I-1)*U(I-1))*AFLO
   52 CONTINUE
      DO 53 I=2,MP3
   53 DM(I)=DM(I-1)+DM(I)
      FLOTOT=DM(MP3)
      DO 51 I=1,MP3
   51 DM(I)=DM(I)/FLOTOT
C
      WMIX=F2A/WFU+(1.-F2A)*.03448
      ROA=PRESS/TA/GASCON/WMIX
      FLOA=ROA*UA*.5*R0**2
      PSII=FLOA
      PEI=FLOTOT
      PSIE=PSII+PEI
C
C     -----------------------------------------------------------------
CHAPTER666666666666666666666666666666666  THERMODYNAMIC PROPERTIES  666666
C   ********************  START OF MAIN LOOP  ********************
   60 CONTINUE
C
C     ---------------------------------------------------------- TEST 1
      IF(ITEST) 602,601,602
  602 LAB(1)=6HTEST 1
      LAB(2)=6H
      WRITE(6,100) LAB,P(1),PRESS,DX,PSII,PSIE,PEI,FRA,ULIM,PEILIM,AFAC,
     1             AEIDLM
      LAB(1)=1HU
      LAB(2)=6H
      WRITE(6,100) LAB,(U(I),I=1,MP3)
      LAB(1)=6HF(1,I)
      LAB(2)=6H
      WRITE(6,100) LAB,(F(1,I),I=1,MP3)
      LAB(1)=6HF(2,I)
      LAB(2)=6H
      WRITE(6,100) LAB,(F(2,I),I=1,MP3)
      LAB(1)=6HF(3,I)
      LAB(2)=6H
      WRITE(6,100) LAB,(F(3,I),I=1,MP3)
      LAB(1)=6HF(4,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(4,I),I=1,MP3)
      LAB(1)=6HF(5,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(5,I),I=1,MP3)
      LAB(1)=6HF(6,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(6,I),I=1,MP3)
      LAB(1)=6HF(7,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(7,I),I=1,MP3)
  601 CONTINUE
C
      DO 200 I=1,MP3
  200 P(I)=P(I)+DPDX(I)*DXOLD(I)
      IF(MASSTR.NE.0) GO TO 64
      DO 65 I=1,MP3
      FS(JT,I)=AMAX1(1.,(F(JH,I)-.5*U(I)**2)/CP)
   65 RHO(I)=P(I)*WMIX/FS(JT,I)/GASCON
      GO TO 66
```

```
   64 DO 61 I=1,NP3
      GO TO (606,605), INERT
  605 FUB=F(JFUOX,I)-F(JFU,I)
      FS(JOX,I)=RATIO1*F(JFU,I)+RATIO3*F(JCO,I)+RATIO2-(RATIO2+RATIO1)
     1   *F(JFUOX,I)
      FS(JCO2,I)=WCO2*CI*FUB/WFU-WCO2*F(JCO,I)/WCO
      FS(JH2O,I)=HY*WH2O*FUB/WFU/2.
  606 FS(JN2,I)=1.-F(JFU,I)-FS(JCO2,I)-F(JCO,I)-FS(JOX,I)-FS(JH2O,I)
      ENTH=F(JH,I)-.5*U(I)*U(I)-HFU*F(JFU,I)
      FS(JT,I)=AMAX1(ENTH/CP,100.)
      WMIX=F(JFU,I)/WFU+FS(JCO2,I)/WCO2+F(JCO,I)/WCO+FS(JOX,I)/WOX+
     1   FS(JH2O,I)/WH2O+FS(JN2,I)/WN2
   61 RHO(I)=P(I)/FS(JT,I)/WMIX/GASCON
   66 CONTINUE
      RHO(2)=RHO(1)
      RHO(NP2)=RHO(NP3)
C     ---------------------------------------------------- TEST 2
      IF(ITEST) 604,603,604
  604 LAB(1)=6HTEST 2
      LAB(2)=6H
      WRITE(6,100) LAB,PRESS,DX,DPDDX,PDGSCN
      LAB(1)=6HFS(1,I
      LAB(2)=1H)
      WRITE(6,100) LAB,(FS(1,I),I=1,NP3)
      LAB(1)=6HFS(2,I
      LAB(2)=1H)
      WRITE(6,100) LAB,(FS(2,I),I=1,NP3)
      LAB(1)=6HFS(3,I
      LAB(2)=1H)
      WRITE(6,100) LAB,(FS(3,I),I=1,NP3)
      LAB(1)=6HRHO(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(RHO(I),I=1,NP3)
  603 CONTINUE
C     ------------------------------ ADJUST R(1)
      IF (KIN.EQ.2.AND.KRAD.EQ.1) R(1)=RA+SQRT(ABS(2.*PSI1/(RHO(1)*
     1                                                           U(1))))
C
      RI=TAB(ZUI,ZRI,ARI,NDP)
      RE=TAB(ZUE,ZRE,ARE,NDP)
      XI=TAB(ZUI,ZRI,XRI,NDP)
      XE=TAB(ZUE,ZRE,XRE,NDP)
      CSALFA=(RE-RI)/SQRT((RE-RI)**2+(XE-XI)**2)
      IF (KIN.EQ.1.AND.KRAD.EQ.1) R(1)=RI
C     -----------STRIDE1-----------STRIDE1-----------STRIDE1---------STRIDE1
      CALL STRIDE(1)
C
C     --------------------------------------------------------------------
CHAPTER77777777777777777777777777777777777777777777  FORWARD STEP  777777777
      I1=MODE(ZUE,ZRE,NDP)
      I2=MODE(ZUI,ZRI,NDP)
      IF (I2-I1) 60,69,58
   58 WRITE (6,67) ISTEP,I2,I1
   67 FORMAT (' **ERROR IN MAIN AT ISTEP=',I4,' I2=',I3,' I1=',I3,' **')
   69 I=AMIN0(I1,I2)
      DFACI=ZRI(I+1)-ZRI(I)
      DFACE=ZRE(I+1)-ZRE(I)
      DMAX=AMAX1(DFACI,DFACE)
      DFACI=DFACI/DMAX
      DFACE=DFACE/DMAX
      IDIFIX=5
C
      DZM=FRACT(NP3)
      IF (ISTEP.LT.50) DZM=.1*DZM
C
      DLI=ZRI(I+1)-ZUI
      DLE=ZRE(I+1)-ZUE
      IF (DZM*DFACI.LE.DLI.AND.DZM*DFACE.LE.DLE) GO TO 79
      RAT=(ZRE(I+2)-ZRE(I+1))/(ZRI(I+2)-ZRI(I+1))
      DFAC=(DLE+RAT*(DZM-DLI))/DZM
      IF (DFAC.GT.1.3) GO TO 78
      DFACI=1.0
      DFACE=DFAC
      GO TO 72
   78 DFAC=(DLI+(DZM-DLE)/RAT)/DZM
      IF (DFAC.GT.1.0) GO TO 79
      DFACE=1.0
```

```
      DFACI=DFAC
   72 IDZFIX=1
   79 IF (ISTEP.GE.IEND) GO TO 70
      IF (DZM*DFACI.LT.ZEND-ZUI) GO TO 70
      DZM=(ZEND-ZUI)/DFACI
      IDZFIX=1
      IEND=ISTEP+1
   70 IF (ISTEP.GE.IOUT) GO TO 71
      IF (DZM*DFACE.LT.ZOUT-ZUE) GO TO 71
      DZM=(ZOUT-ZUE)/DFACE
      IDZFIX=1
      IOUT=ISTEP+1
   71 IF (DZM*DFACE.LT.ZULAST-ZUE) GO TO 77
      DZM=(ZULAST-ZUE)/DFACE
      IDZFIX=1
   77 IF (DZM.GT.1.E-10) GO TO 73
      IFIN=1
      GO TO 1011
   73 DZMIN=.005*FRA*Y(NP3)
      DYFAC=(DFACE-DFACI)/(Y(NP3)-Y(1))
      DO 76 I=1,NP3
      DZOLD(I)=AMAX1(DZMIN,DZ(I))
   76 DZ(I)=DZM*(DFACI+DYFAC*(Y(I)-Y(1)))
      DZ(2)=DZ(1)
      DZ(NP2)=DZ(NP3)
      ZDI=ZUI+DZ(1)
      ZDE=ZUE+DZ(NP3)
C ---- FURTHER ADJUSTMENTS TO DZ ARE MADE IN CHAPTERS 8 AND 9.
C
C     -------------------------------------------------------------------
CHAPTER8888888888888888888888888888 ADJUST LONGITUDINAL CONDITIONS 8888888
C
C     CHAPTER8A ------------------------------------BOUNDARY CONDITIONS
C     ------------------ I BOUNDARY
      IF(ISTEP-IAX) 8000,50,84
 8000 IF(ISTEP-IEND) 8052,83,84
C     ------------------------------- WALL
 8052 KIN=1
      U(1)=0.
      RPI=0.
      IF(ISTEP.EQ.0) TAUI=0.
      EWALL=0.
      DO 81 J=1,4
      INDI(J)=2
   81 AJI(J)=0.
      DO 74 J=5,7
      INDI(J)=1
   74 F(J,1)=0.0
      IF (IFLUX.EQ.0) GO TO 84
      INDI(JH)=1
      FS(JT,1)=TWALL
      F(JH,1)=CP*TWALL+FLOAT(PASSTR)*WFU*F(JFU,1)
      GO TO 84
C     --------------------------- FREE
   83 KIN=2
      TAUI=0.
      U(1)=UA
      RU(1)=RHO(1)*U(1)
      F(JH,1)=F1A
      F(JFU,1)=F2A
      F(JFUOX,1)=F3A
      F(JCO,1)=0.0
      F(JVT,1)=R(1)*VTA
      F(JK,1)=AKFAC*UA*UA
      F(JD,1)=CD*F(JK,1)**1.5/ALR
      GO TO 84
C     ---------------------- SYMMETRY AXIS
   80 KIN=3
      RPI=0.
      R(1)=RA
      PSII=0.
      TAUI=0.
C     ---------------------- E BOUNDARY
   84 IF(ISTEP-IOUT) 8004,85,85
C     ------------------------- WALL
 8004 KEX=1
      U(NP3)=0.
```

```
      RRE=0.
      IF(ISTEP.EQ.0) TAUE=0.
      EWALL=0.
      DO 82 J=1,4
      IMOE(J)=2
   82 AJE(J)=0.
      DO 75 J=5,7
      IMOE(J)=1
   75 F(J,NP3)=0.0
      IF (IFLUX.EQ.0) GO TO 86
      IMOE(JM)=1
      FS(JT,NP3)=TWALL
      F(JH,NP3)=CP*TWALL+FLOAT(MASSTR)*HFU*F(JFU,NP3)
      GO TO 86
C     ----------------------------------------------FREE
   85 KEX=2
      TAUE=0.
      U(NP3)=UD
      RU(NP3)=RHO(NP3)*U(NP3)
      F(JH,NP3)=F1D
      F(JFU,NP3)=F2D
      F(JFUOX,NP3)=F3D
      F(JCO,NP3)=0.0
      F(JUT,NP3)=R(NP3)*UTD
      F(JK,NP3)=0.0
      F(JD,NP3)=0.0
C
C     CHAPTER 8B ------------------------------------ DUCT GEOMETRY
   86 IF(ISTEP.GE.IOUT) GO TO 89
      IF(ISTEP.GT.0) GO TO 87
      ADUD=.5*SQRT((R(NP3)-R(1))**2+(XE-XI)**2)*(R(NP3)+R(1))
      IF (KRAD.EQ.0) ADUD=Y(NP3)
   87 ADUU=ADUD
      AFLU=.5*SQRT((R(NP3)-R(1))**2+(XE-XI)**2)*(R(NP3)+R(1))
      IF (KRAD.EQ.0) AFLU=Y(NP3)
      AEX=AFLU-ADUU
      AEXD=AEX/AFLU
      IF (ABS(AEXD).LT.AEXDLM) GO TO 88
      IF (IDZFIX.EQ.1) GO TO 89
      DZFAC=AEXDLM/ABS(AEXD)
      DO 108 I=1,NP3
  108 DZ(I)=DZ(I)*DZFAC
      ZDI=ZUI+DZ(1)
      ZDE=ZUE+DZ(NP3)
   88 RID=TAB(ZDI,ZRI,ARI,NRP)
      IF (KIN.NE.1.AND.KRAD.EQ.1) RID=R(1)
      RED=TAB(ZDE,ZRE,ARE,NRP)
      XID=TAB(ZDI,ZRI,XRI,NRP)
      XED=TAB(ZDE,ZRE,XRE,NRP)
      ADUD=.5*SQRT((RED-RID)**2+(XED-XID)**2)*(RED+RID)
      IF (KRAD.EQ.0) ADUD=SQRT((RED-RID)**2+(XED-XID)**2)
      DA=(ADUD-ADUU)+AFAC*(ADUU-AFLU)
C
C     CHAPTER 8C ------------------------ SUBSONIC PRESSURE GRADIENT
C     ---------------------------UBAR
   89 UBAR=0.
      DO 825 I=2,NP1
  825 UBAR=UBAR+(U(I)+U(I+1))*OMD(I)
      UBAR=.5*UBAR
      IF(KIN.EQ.2) UBAR=(UBAR-UA)*PEI/PSIE+UA
C     ---------------------------SUBSONIC FLOW
  803 IF (ISTEP-IOUT) 822,823,823
  823 DP=0.
      GO TO 824
C     ----------------------------------- CONFINED SUBSONIC FLOW
  822 GO TO (830,835), IDPDX
  835 IF (ISTEP.EQ.0.OR.KIN.EQ.2) GO TO 830
C     ------------      GRID FILLING DUCT  VERSION    ----------
      RDUBAR=PEI/ADUU
      RDBAR=RDUBAR/UBAR
      DUDP=-1./(RDUBAR*(TAUE*R(NP3)*DZ(NP3)+TAUI*R(1)*DZ(1))/ADUU/UBAR)
      UDPDDP=RDUBAR/GAMMA/P(NP3)
      DRDU=RDUBAR*(AFLU/ADUU-1.)
      DPC=DRDU/(RDBAR*DUDP+UDPDDP)
      UFAC=DPC*DUDP/UBAR+1.
C     -------    ADJUST VELOCITY PRESSURE AND DENSITY PROFILES  -------
      DO 840 I=1,NP3
```

```
      U(I)=U(I)*UFAC
      P(I)=P(I)+DPC
  940 RHO(I)=RHO(I)*(1.+GAMMA*DPC/P(I))
C ------- RECALCULATE DISTANCES ----------
      CALL STRIDE(1)
      DP=DP+DPC
      GO TO 824
C ------------- STANDARD GENMIX VERSION ----------
  830 FLOTOT=PSIE-PSII*FLOAT(1/KIN)
      DYNMED=UBAR*FLOTOT/AFLU
      SHPSTR=TAUI*R(1)*DZ(1)+TAUE*R(NP3)*DZ(NP3)
      DP=(DYNMED*DA-SHPSTR+2.*RME*DZ(NP3)*UBAR)/ADUD
  824 CONTINUE
C -------- 2*FLOW AREAS ------------
      DO 307 I=2,NP2
  307 RDY(I)=PEI*(OM(I+1)-OM(I-1))/RHO(I)/U(I)
      GO TO (310,312,312), KIN
  310 RDY(2)=(R(1)+.5*(R(2)+R(3)))*YI
      GO TO 313
  312 RDY(2)=PEI*OM(3)/RHO(3)/U(3)
  313 GO TO (314,315,315), KEX
  314 RDY(NP2)=(R(NP3)+.5*(R(NP2)+R(NP1)))*YE
      GO TO 316
  315 RDY(NP2)=PEI*(1.-OM(NP1))/RHO(NP1)/U(NP1)
  316 CONTINUE
      RDY(1)=0.0
      RDY(NP3)=0.0
C ---------- PRESSURE GRADIENT d/SWIRL AND RADIUS ------------------
C ---------- OF CURVATURE EFFECTS INCLUDED ------------------------
      VOR2=(F(JVT,NP2)/(.75*R(NP2)+.25*R(NP1))**2)**2
      PALFA=0.5*PEI*CSALFA
      PD=0.
      DPDX(NP2)=0.0
      DO 225 JI=3,NP2
      I=NP3-JI+1
      IF (ISWRL) 226,226,227
  227 VOR2P1=VOR2
      RII=R(I)
      IF (I.EQ.2) RII=.75*R(2)+.25*R(3)
      VOR2=(F(JVT,I)/RII**2)**2
      PD=PD-PALFA*(VOR2/U(I)+VOR2P1/U(I+1))*DMD(I)
  226 IF (ICURV) 228,228,229
  229 RCV=RCURV(ZUI,ZUE,Y(I),Y(NP3))
      IF (I.EQ.2) RCV1=RCV
      IF (I.EQ.NP1) RCV2=RCV
      ALFA=1.+Y(I)/RCV
      IF (RCV.LT.0.) ALFA=1.+(Y(NP3)-Y(I))/ABS(RCV)
      DY=Y(I+1)-Y(I)
      PD=PD-RHO(I)*U(I)*U(I)*DY/ALFA/RCV
  228 CONTINUE
      IF (ISTEP.GT.0) GO TO 224
      PSWPL(I)=PD
      P(I)=P(I)+PD
      IF (I.EQ.2) P(1)=P(2)
  224 DPDX(I)=(PD-PSWPL(I))/DZOLD(I)
  225 PSWPL(I)=PD
      IF (KEX.EQ.2) GO TO 260
      DPDXDA=0.
      SRDY=0.
      DO 250 I=2,NP2
      SRDY=SRDY+RDY(I)
  250 DPDXDA=DPDXDA+DPDX(I)*DZOLD(I)*RDY(I)
      DP=DP-DPDXDA/SRDY
      DO 255 I=2,NP2
  255 DPDX(I)=DPDX(I)+DP/DZOLD(I)
  260 CONTINUE
      DPDX(1)=DPDX(2)
      DPDX(NP3)=DPDX(NP2)
C ------------------------------------------------ TEST 3
  242 IF (ITEST) 802,801,802
  802 LAB(1)=6HTEST 3
      LAB(2)=6H
      WRITE(6,100) LAB,UBAR,DYNMED,DF,DA,DPODX,AEXO,RMI
      WRITE(6,101) LAB,ISTEP,KIN,KEX,IAX,IEND,IOUT
      LAB(1)=4HY(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(Y(I),I=1,NP3)
```

```
      LAB(1)=6HR(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(R(I),I=1,NP3)
      LAB(1)=5HRU(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(RU(I),I=1,NP3)
      LAB(1)=6HDPDX(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(DPDX(I),I=1,NP3)
      LAB(1)=6HPSWRL(
      LAB(2)=6HI)
      WRITE (6,100) LAB,(PSWRL(I),I=1,NP3)
  801 CONTINUE
C
C ------------------------------------------------------------------------
CHAPTER 9999999999999999999999  TRANSPORT AND ENTRAINMENT PROPERTIES  9999
C ----- LAMINAR VISCOSITY ASSUMED TO BE THAT OF AIR ----------------
  900 CONTINUE
      DO 98 I=1,NP3
      IF (FS(JT,I).GT.667.) GO TO 90
      EMU(I)=1.808E-5*(FS(JT,I)/294.4)**0.76
      GO TO 98
   90 EMU(I)=4.464E-5*SQRT(FS(JT,I)/1111.)
   98 CONTINUE
      EMU(2)=EMU(1)
      EMU(NP2)=EMU(NP3)
C     ------------------------------------------------------ TEST 4
      IF(ITEST) 902,901,902
  902 LAB(1)=6HTEST 4
      LAB(2)=6H
      WRITE(6,100) LAB,RMI,RME,PEI
      LAB(1)=6HEMU(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(EMU(I),I=1,NP3)
  901 CONTINUE
C
C     ----------AUX----------AUX----------AUX----------AUX----------AUX
      CALL AUXD(O)
C     ------------------------------- ENTRAINMENT CONTROL.
      IF(KIN.NE.2) GO TO 94
      RAT=ABS((U(3)-U(1))/(U(NP3)-U(1)+1.E-30))
      IF(RAT.LT.ULIM) EM U(2)=EM U(2)*RAT/ULIM
      RMI=2.*EM U(2)
   94 CONTINUE
      IF(KEX.NE.2) GO TO 97
      RAT=ABS((U(NP1)-U(NP3))/(U(NP3)-U(1)+1.E-30))
      RME=-2.*EM U(NP1)
      IF(RAT.LT.ULIM) RME=RME*(RAT/ULIM)**2
   97 IF (IDZFIX.EQ.1) GO TO 96
C     ---------- LIMIT ON INCREMENT IN PEI.
      IF (ABS(RMI)*DZ(1)+ABS(RME)*DZ(NP3).LT.PEI*PEILIM) GO TO 96
      DZFAC=PEI*PEILIM/(ABS(RMI)*DZ(1)+ABS(RME)*DZ(NP3))
      DO 99 I=1,NP3
   99 DZ(I)=DZ(I)*DZFAC
      ZDI=ZUI+DZ(1)
      ZDE=ZUE+DZ(NP3)
   96 CONTINUE
C     ---------- ADJUSTMENT OF DX TO REACH AXIS.
      IF(KIN.EQ.1) GO TO 95
      IF(ISTEP.GE.IAX) GO TO 95
      IF (PSII.GT.RMI*DZ(1).OR.IAX.EQ.ISTEP+1) GO TO 95
      RMI=PSII/DZ(1)
      IAX=ISTEP+1
C
C     ----------STRIDE2----------STRIDE2----------STRIDE2--------STRIDE2
   95 CALL STRIDE(2)
C
C ------------------------------------------------------------------------
CHAPTER 10 10 10 10 10 10 10 10 10 10 10 10 10 10   OUTPUT   10 10 10
 1000 IF(ISTEP.GT.0) GO TO 106
      WRITE (6,9000)
 9000 FORMAT (1H1)
CHAPTER 10A ---------------------------------- HEADINGS
C
      WRITE (6,1013) TITLE,MODEP,IDPDX,MODEL,MASSTR,INERT,KRAD,IFLUX
 1013 FORMAT (1H1,12A6/12A6/7H MODEP=,I3,7H IDPDX=,I3,7H MODEL=,I3,
     1 8H MASSTR=,I3,7H INERT=,I3,6H KRAD=,I3,7H IFLUX=,I3)
```

```
C
      WRITE (6,1010) UA,UD,TA,TD,RA,RB,ZEND,ZOUT,ZULAST,PRESS,
     1 PREXP1,ARCON1,CR1,PREXP2,ARCON2,CR2,VTA,VTD
 1010 FORMAT (1H ,1X,2HUA,8X,2HUD,8X,2HTA,8X,2HTD,8X,2HRA,8X,2HRB,8X,
     1 4HZEND,6X,4HZOUT,6X,6HZULAST,4X,5HPRESS/1H ,1P10E10.3/1H ,
     2 7H PREXP1,4X,6HARCON1,4X,3HCR1,7X,6HPREXP2,4X,6HARCON2,4X,
     3 3HCR2,7X,3HVTA,7X,3HVTD/1X,1P10E10.3)
C
      LAB(1)=5HOMEGA
      LAB(2)=6H
      WRITE(6,100) LAB,(OM(I),I=1,NP3)
      PRESS1=PRESS
      WRITE (6,1003)
 1003 FORMAT (//13X,*INTERNAL BOUNDARY*,27X,*EXTERNAL BOUNDARY*,/13X,
     1 16(1H-),28X,16(1H-)//2(3X,*I*,10X,*X*,11X,*R*,11X,*Z*,9X))
      DO 1004 I=1,NBP
 1004 WRITE (6,1005) I,XRI(I),ARI(I),ZRI(I),I,XRE(I),ARE(I),ZRE(I)
 1005 FORMAT (2(1X,I3,3(1X,E11.4),4X))
      IF (ICURV.EQ.0) GO TO 1009
      WRITE (6,1007)
 1007 FORMAT (//13X,*INTERNAL BOUNDARY*,27X,*EXTERNAL BOUNDARY*,/13X,
     1 16(1H-),28X,16(1H-)//2X,*I*,9X,*Z*,19X,*RCVI*,21X,*I*,9X,*Z*,
     2 16X,*RCVE*)
      NRCV=MAX0(NRCVI,NRCVE)
      DO 1051 I=1,NRCV
      WRITE (6,1054) I,ZSI(I),RCVI(I),I,ZSE(I),RCVE(I)
 1054 FORMAT (1X,I2,2X,E11.4,10X,E11.4,19X,I2,2X,E11.4,10X,E11.4)
 1051 CONTINUE
 1050 FORMAT (1H )
 1009 WRITE (6,1050)
  106 CONTINUE
C     ----------------------------------------------------------- TEST 5
      IF(ITEST) 1002,1001,1002
 1002 LAB(1)=6HTEST 5
      LAB(2)=6H
      WRITE(6,100) LAB,RMI,RME,DX
 1001 CONTINUE
C
CHAPTER 10B  ---------------------------------------  TESTS FOR PRINTOUT
C     ----- IPRINT=0 GIVES NO OUTPUT,  =1 GIVES SINGLE VARIABLES ONLY,
C                  =2 GIVES BOTH SINGLE AND ARRAY (PROFILE) VARIABLES.
 1011 IPRINT=0
      IF (MOD(ISTEP,NSTAT).EQ.0) IPRINT=1
      IF (MOD(ISTEP,NPROF).EQ.0) IPRINT=2
      IF(ISTEP.EQ.IEND.OR.ISTEP.EQ.IAX.OR.ISTEP.EQ.IOUT) IPRINT=2
      IF(ITEST.NE.0.OR.IFIN.NE.0) IPRINT=2
      IF (MOD(ISTEP,NPLOT).EQ.0.AND.ISTEP.GT.0) IPRINT=3
C     ----- THE NEXT STATEMENT PROVIDES A PLOT JUST PRIOR TO TERMINATION
      IF (ZUE.GE.ZULAST.OR.IFIN.NE.0.OR.ISTEP.EQ.LASTEP) IPRINT=3
C
CHAPTER 10C  ------------------------------SINGLE STATION VARIABLES.
      IF(IPRINT.EQ.0) GO TO 110
      PRESSD=P(NP3)/PRESS1-1.
      WRITE (6,1030) ISTEP,IAX,IEND,IOUT,KIN,KEX,DZ(1),DZ(NP3),PSII,
     1 PSIE,RMI,RME,PEI,PRESSD,AEXD
 1030 FORMAT(7H0ISTEP=,I5,5H IAX=,I5,6H IEND=,I5,6H IOUT=,I5,5H KIN=,I2,
     1 5H KEX=,I2,5H DZI=,1PE11.3,5H DZE=,1PE11.3,6H PSII=,E11.3,
     2 6H PSIE=,E11.3/5H RMI=,E11.3,5H RME=,E11.3,5H PEI=,E11.3,
     3 9H PRESSD=,E11.3,6H AEXD=,E11.3)
      WRITE (6,1015) XI,XE,RI,RE,RCVI,RCV2,CSALFA
 1015 FORMAT (4H XI=,1PE11.3,4H XE=,1PE11.3,4H RI=,1PE11.3,4H RE=,
     1 1PE11.3,6H RCVI=,1PE11.3,6H RCVE=,1PE11.3,8H CSALFA=,1PE11.3)
C
C
      UBAR=0.
      DO 1020 J=1,NF
      AJI0(J)=0.0
      AJE0(J)=0.0
 1020 FLUX(J)=0.
      DO 1021 I=2,NP1
      UBAR=UBAR+DMD(I)*(U(I)+U(I+1))
      DO 1021 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1021
      FLUX(J)=FLUX(J)+DMD(I)*(F(J,I)+F(J,I+1))
 1021 CONTINUE
      UBAR=.5*UBAR
      UFLUX=PEI*UBAR
```

```
      DO 1022 J=1,NF
 1022 FLUX(J)=.   *FI*FLUX(J)
C
      UREF=UBAR
      RUREF=PEI/.5/(R(1)+R(NP3))/Y(NP3)
      DO 1023 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1023
      DFI(J)=FLUX(J)/PEI-F(J,1)
      DFE(J)=DFI(J)+F(J,1)-F(J,NP3)
 1023 CONTINUE
      UFLUX=UFLUX-PSIE*U(NP3)+U(1)*PSII
 1043 FLUX(3)=FLUX(3)-PSIE*F3D+F3A*PSII
 1042 FLUX(2)=FLUX(2)-PSIE*F2D+F2A*PSII
 1041 FLUX(1)=FLUX(1)-PSIE*F1D+F1A*PSII
C
      WRITE (6,1031) ZUI,ZUE,UFLUX,(FLUX(J),J=1,NF)
 1031 FORMAT (5H ZUI=,1PE11.3,5H ZUE=,1PE11.3,7H UFLUX=,E10.3,
     1 9H FLUX(J)=,(7E10.3))
C
      IF(KIN.NE.1) GO TO 1024
      TAUID=TAUI/UREF/RUREF
      DO 1025 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1025
      AJID(J)=AJI(J)/RUREF/DFI(J)
 1025 CONTINUE
      WRITE(6,1029) KIN,TAUID,(AJID(J),J=1,NF)
 1029 FORMAT (5H KIN=,I2,7H TAUID=,1PE11.3,9H AJID(J)=,7E11.3)
C
 1024 IF(KEX.NE.1) GO TO 1026
      TAUED=TAUE/UREF/RUREF
      DO 1027 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1027
      AJED(J)=AJE(J)/RUREF/DFE(J)
 1027 CONTINUE
      WRITE(6,1028) KEX,TAUED,(AJED(J),J=1,NF)
 1028 FORMAT (5H KEX=,I2,7H TAUED=,1PE11.3,9H AJED(J)=,7E11.3)
 1026 CONTINUE
C
CHAPTER 100   ----------------------------------PROFILES AND OTHER ARRAYS.
      IF(IPRINT.EQ.1) GO TO 110
C
      LAB(1)=6HR1,Y'S
      LAB(2)=6H
      DIV=1.
      DO 1095 I=1,NP3
 1095 OUT(I)=Y(I)/DIV
      WRITE (6,100) LAB,R(1),(OUT(I),I=2,NP2,ITHIN),Y(NP3)
      XAXIS=4HY(I)
      DO 1085 I=1,NP3
 1085 XPLOT(I)=OUT(I)
C
      LAB(1)=1HU
      LAB(2)=6H
      SUB=0.
      DIV=1.
      IF(KIN.EQ.3) SUB=U(NP3)
      IF(KIN.EQ.3) DIV=U(1)+1.E-30
      DO 1094 I=1,NP3
 1094 OUT(I)=(U(I)-SUB)/DIV
      IF (NOVEL.NE.1) WRITE (6,100) LAB,U(1),(OUT(I),I=2,NP2,ITHIN),
     1 U(NP3)
      NV=1
      YAXES(1,1)=8HVELOCI
      YAXES(1,2)=2HTY
      SYMBOL(1)=1HU
      DO 1084 I=1,NP3
 1084 YPLOT(1,I)=OUT(I)
C
      INDX=0
      DO 1080 KV=1,NF
      KVV=KV+INDX
      IF (IPRNT(KVV).EQ.0) GO TO 1080
      LAB(1)=LAB1(KVV)
      LAB(2)=LAB2(KVV)
      DO 1082 I=1,NP3
 1082 OUT(I)=F(KV,I)
      IF (KV.NE.JVT) GO TO 1075
```

```
      VTMAX=0.
      DO 1086 I=2,NP3
      DIV=R(I)
      IF (I.EQ.2) DIV=.75*R(2)+.25*R(3)
      IF (I.EQ.NP2) DIV=.75*R(NP2)+.25*R(NP1)
      OUT(I)=OUT(I)/DIV
 1086 VTMAX=AMAX1(VTMAX,OUT(I))
 1075 IF (KV.NE.JD) GO TO 1076
      DO 1077 I=1,NP3
 1077 OUT(I)=CO*F(JK,I)**1.5/(OUT(I)+1.E-20)
 1076 WRITE (6,100) LAB,F(KV,1),(OUT(I),I=2,NP2,ITHIN),F(KV,NP3)
      IF (IPLOT(KVV).EQ.0) GO TO 1060
      NY=NY+1
      YAXES(NY,1)=LAB1(KVV)
      YAXES(NY,2)=LAB2(KVV)
      SYMBOL(NY)=SYM(KVV)
      DO 1090 I=1,NP3
 1090 YPLOT(NY,I)=OUT(I)
 1060 CONTINUE
C
      INDX=NF
      DO 1180 KV=1,NFS
      KVV=KV+INDX
      IF (IPRNT(KVV).EQ.0) GO TO 1180
      LAB(1)=LAB1(KVV)
      LAB(2)=LAB2(KVV)
      DO 1182 I=1,NP3
 1182 OUT(I)=FS(KV,I)
      WRITE (6,100) LAB,FS(KV,1),(OUT(I),I=2,NP2,ITHIN),FS(KV,NP3)
      IF (IPLOT(KVV).EQ.0) GO TO 1180
      NY=NY+1
      YAXES(NY,1)=LAB1(KVV)
      YAXES(NY,2)=LAB2(KVV)
      SYMBOL(NY)=SYM(KVV)
      DO 1190 I=1,NP3
 1190 YPLOT(NY,I)=OUT(I)
 1180 CONTINUE
C
      LAB(1)=6HPRESS
      IF (ISWRL.EQ.0.AND.ICURV.EQ.0) GO TO 1100
      LAB(2)=6H
      SUB=P(NP3)
      DIV=1.0
      DO 1112 I=1,NP3
 1112 OUT(I)=(P(I)-SUB)/DIV
      WRITE (6,100) LAB,P(1),(OUT(I),I=2,NP2,ITHIN),P(NP3)
 1100 IF (MODEL.NE.2) GO TO 1104
      LAB(1)=6HAMU(I)
      LAB(2)=6H
      WRITE (6,100) LAB,AMU(1),(AMU(I),I=2,NP2,ITHIN),AMU(NP3)
 1104 CONTINUE
      IF(IPRINT.EQ.2) GO TO 110
      WRITE (6,1070) ZUE,ISTEP
 1070 FORMAT (1H ,12HPLOT AT ZUE=,1PE11.3,8H, ISTEP=,I5)
      DO 1071 J=1,NY
      YPLOT(J,2)=YPLOT(J,1)
 1071 YPLOT(J,NP2)=YPLOT(J,NP3)
      CALL PLOTS(XPLOT,43,NP3,XAXIS,YPLOT,10,NY,YAXES,SYMBOL)
C -----------------------------------------------------------------------
CHAPTER 11  11  11  11  11  11  11  11  11  11  11  END OF MAIN LOOP
  110 IF (ISTEP.GE.LASTEP.OR.ZUE.GE.ZULAST.OR.IFIN.NE.0) GO TO 111
C
C     ----------STRIDE3----------STRIDE3----------STRIDE3--------STRIDE3
      CALL STRIDE(3)
      IF(IFIN) 1011,60,111
C
C     ---------------------------------------------------- TERMINATION
  111 WRITE (6,112) ISTEP,LASTEP,ZUE,ZULAST,IFIN
  112 FORMAT(23H TERMINATED WITH ISTEP=,I5,8H LASTEP=,I5,
     1 5H ZUE=,1PE11.3,8H ZULAST=,E11.3,6H IFIN=,I3)
C -----------------------------------------------------------------------
  120 CONTINUE
      STOP
  100 FORMAT (1H0,A6,A2,1P11E11.3/(9X,11E11.3))
  101 FORMAT (1H0,A6,A2,11I11)
      END
```

```
                 PROGRAM MAIN        73/74    OPT=0 TRACE                 FTN 4.6+439          08/24/78  10.30.04        PAGE     13
CARD NR. SEVERITY  DETAILS     DIAGNOSIS OF PROBLEM

   319      I                  AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   528      I                  AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   556      I                  AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   560      I                  AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
```

```
      FUNCTION RCURV (ZI,ZE,Y,YT)                                         RC        1
      COMMON/CONC/ARE(40),ZRE(40),XRE(40),ARI(40),ZRI(40),XRI(40),        CONC      2
     1 RBP,NRCVI,NRCVE,ZSI(30),ZSE(30),RCVI(30),RCVE(30)                  CONC      3
      DATA RCVMX/1000./                                                   RC        4
C ***************  INTERNAL BOUNDRY RADIUS OF CURVATURE  *************** RC        5
      IF (ZI.LT.ZSI(1).OR.ZI.GT.ZSI(NRCVI)) GO TO 10                      RC        6
      RCV1=TAB(ZI,ZSI,RCVI,NRCVI)                                         RC        7
      GO TO 15                                                            RC        8
   10 RCV1=RCVMX                                                          RC        9
C ***************  EXTERNAL BOUNDRY RADIUS OF CURVATURE  *************** RC       10
   15 IF (ZE.LT.ZSE(1).OR.ZE.GT.ZSE(NRCVE)) GO TO 20                      RC       11
      RCV2=TAB(ZE,ZSE,RCVE,NRCVE)                                         RC       12
      GO TO 25                                                            RC       13
   20 RCV2=RCVMX                                                          RC       14
C **************  ACTUAL RCV VALUE IS LINEAR INTERPOLATION  ************* RC       15
   25 RCURV=RCV1+(RCV2-RCV1)*Y/YT                                         RC       16
      RETURN                                                              RC       17
      END                                                                 RC       18
```

```
FUNCTION TAB        73/74    OPT=0 TRACE                FTN 4.6+439        08/24/78  10.30.04        PAGE    1

      FUNCTION TAB (X,XX,YY,NTAB)
      DIMENSION XX(1),YY(1)
      IF (NTAB.GT.0) GO TO 5
      TAB=0.0
      RETURN
    5 F=1.
      IF (XX(1).GT.XX(2)) F=-F
      DO 10 J=1,NTAB
      I=J
      IF (F*(XX(I)-X)) 10,40,20
   10 CONTINUE
   20 IF (I.NE.1) GO TO 30
      I=2
   30 J=I-1
      DEL=XX(I)-XX(J)
      IF (DEL.EQ.0.0) GO TO 50
      TAB=(YY(I)*(X-XX(J))-YY(J)*(X-XX(I)))/DEL
      RETURN
   40 TAB=YY(I)
      RETURN
   50 WRITE (6,60) X,I,J
      CALL EXIT
   60 FORMAT (' *** ERROR IN SUBROUTINE TAB ***',E15.4,2I5)
      END

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM
    7       I        XX        ARRAY REFERENCE OUTSIDE DIMENSION BOUNDS.
```

```
FUNCTION MODE        73/74    OPT=0 TRACE              FTN 4.6+439         08/24/78  10.30.04        PAGE     1

            FUNCTION MODE (X,XX,N)                                              MO         2
            DIMENSION XX(1)                                                     MO         3
            IF (X.LT.XX(1).OR.X.GT.XX(N)) GO TO 20                              MO         4
            DO 10 I=2,N                                                         MO         5
            II=I-1                                                              MO         6
            IF (X.GE.XX(II).AND.X.LT.XX(I)) GO TO 15                            MO         7
         10 CONTINUE                                                            MO         8
         15 MODE=II                                                             MO         9
            RETURN                                                              MO        10
         20 WRITE (6,25) X,XX(1),XX(N)                                          MO        11
         25 FORMAT (' ** ERROR IN FUNCTION MODE **',3G15.5)                     MO        12
            RETURN                                                              MO        13
            END                                                                 MO        14
```

```
      SUBROUTINE AUX(NV)
      COMMON/COMA/A(43),AJE(7),AJI(7),B(43),C(43),CSALFA,D(43),DPDX(43),
     1 DI,EMU(43),F(7,43),FS(5,43),IAX,IEND,IFIN,INDE(7),INDI(7),IOUT,
     2 ISTEP,ITEST,IUTRAP,JS,JSW,JV,JT,KEX,KIN,KRAD,N,NB2,NF,NOVEL,NP1,
     3 NP2,NP3,OM(43),OMD(43),P(43),PEI,PR(7),PREF(7),PSIE,PSII,R(43),
     4 RHO(43),RME,RMI,RU(43),SD(43),SU(43),TAUE,TAUI,U(43),XD,XU,
     5 Y(43),YE,YI,PSWRL(43),RDY(43),ISOLVE(7),US(43),AMU(43),
     5 DZ(43),DZDLD(43),ZJI,ZUE,ZDI,ZDE,DPDDX(43),
     6 JH,JFU,JFUDX,JCB,JVI,JK,JB,JBK,JT,JH2,JH2D,JCB2
      COMMON/COMB/AK,ALMG,EWALL,FR,N,NFU,INERT,MASSTR,MODEL,PRESS,
     1 UBAR,WFAC,C1,C2,CD,C2VT,AKFAC,ALFAC,ARCON1,ARCON2,PREXP1,CB75,
     2 PREXP2,CR1,CR2,MODER,MODCP,RATIO1,RATIO2,RATIO3,RATIO4
C/-------- SUBROUTINE FOR PROGRAM GENMIX 4A
      DIMENSION LAB(2),DUDY(43),GENR(43),EMUT(43),EMUL(43)
      DIMENSION SUFU(43),SDFU(43)
C
      ENTRY AUXO
C     -------- CALCULATE TURB VISCOSITY FROM TWO EQUATION MODEL --------
      IF (MODEL.EQ.1) GO TO 200
      DO 112 I=1,NP3
      EMUL(I)=EMU(I)
      RT=RHO(I)*F(JK,I)**2/(F(JB,I)*EMUL(I)+1.0E-30)
      CDD=CD*EXP(-2.5/(1.0+RT/50.))
      EMUT(I)=CDD*RHO(I)*F(JK,I)*F(JK,I)/(F(JB,I)+1.0E-30)
      EMU(I)=EMU(I)+EMUT(I)
  112 AMU(I)=EMU(I)
C     ----------------------------------------- TEST 10
  200 IF (ITEST) 202,201,202
  202 LAB(1)=6HTEST 1
      LAB(2)=6H0
      WRITE (6,100) LAB
      LAB(1)=6HEMU(I)
      LAB(2)=6H
      WRITE (6,100) LAB,(EMU(I),I=1,NP3)
  201 CONTINUE
C     ---------------- MODIFICATION OF EMU ARRAY
      DO 23 I=2,NP2
   23 EPU(I)=.5*(EMU(I+1)+EMU(I))
      DO 24 I=2,NP1
   24 EM U(I)=EMU(I)/(Y(I+1)-Y(I))
      IF (KRAD.EQ.0) GO TO 300
      DO 26 I=2,NP1
   26 EM U(I)=EM U(I)*.5*(R(I)+R(I+1))
  300 CONTINUE
      RETURN
C     ************************    SOURCE TERMS     ********************
      ENTRY SOURCE
      IF (NV.NE.0) GO TO 500
C     ------ VELOCITY U
      DO 308 I=2,NP2
  308 US(I)=D*DI(I)*RDY(I)
      GO TO 6000
C     --------------------- KINETIC HEATING.
  500 IF (NV.NE.JH) GO TO 1000
C     ------ TEMPORARY USE OF SD ARRAY.
      GO TO (303,304), NOVEL
  303 DO 305 I=1,NP3
      SU(I)=0.
  305 SD(I)=0.
      GO TO 306
  304 DO 30 I=2,NP2
   30 S D(I)=U(I)*U(I)
      DO 31 I=2,NP1
   31 S D(I)=EM U(I)*(S D(I+1)-S D(I))
      S D(1)=0.
      S D(NP2)=0.
      DO 32 I=2,NP2
      T=(1.-1./PREF(1))*0.5
   32 SU(I)=(S D(I)-S D(I-1))*T
      DO 33 I=2,NP1
   33 SD(I)=0.
C     ----------------------------------------- TEST 11
  306 IF(ITEST) 302,301,302
  302 LAB(1)=6HTEST 1
      LAB(2)=1H1
      WRITE(6,100) LAB
      LAB(1)=6HSD(I
```

```
      LAB(2)=1H)
      WRITE(6,100) LAB,(SD(I),I=1,NP3)
      LAB(1)=6HSU(I
      LAB(2)=1H)
      WRITE(6,100) LAB,(SU(I),I=1,NP3)
  301 CONTINUE
      GO TO 6000
C     ------------------------------------------------ FUEL ----------
 1000 IF (NV.NE.JFU) GO TO 2000
      DO 90 I=2,NP2
      IF(INERT-1) 45,41,45
   45 F2=F(JFU,I)
      F3=F(JFUOX,I)
      F4=F(JCO,I)
      F6=F(JK,I)
      F7=F(JD,I)
      FS1=FS(JOX,I)
      FS2=FS(JT,I)
      IF(I-2) 52,46,42
   46 F2=F2+.25*(F(JFU,3)-F2)
      F3=F3+.25*(F(JFUOX,3)-F3)
      F4=F4+.25*(F(JCO,3)-F4)
      F6=F6+.25*(F(JK,3)-F6)
      F7=F7+.25*(F(JD,3)-F7)
      FS1=FS1+.25*(FS(JOX,3)-FS1)
      FS2=FS2+.25*(FS(JT,3)-FS2)
   42 IF(I-NP2) 43,47,43
   47 F2=F2+.25*(F(JFU,NP1)-F2)
      F3=F3+.25*(F(JFUOX,NP1)-F3)
      F4=F4+.25*(F(JCO,NP1)-F4)
      F6=F6+.25*(F(JK,NP1)-F6)
      F7=F7+.25*(F(JD,NP1)-F7)
      FS1=FS1+.25*(FS(JOX,NP1)-FS1)
      FS2=FS2+.25*(FS(JT,NP1)-FS2)
   43 IF(F2) 41,41,430
  430 IF(FS1) 41,41,431
  431 SOR1=-PREEXP1*RHO(I)**2*FS1*EXP(-ARCON1/FS2)
      GO TO (48,49), MODER
   48 SOR=SOR1
      GO TO 44
   49 SOR2=-CR1*RHO(I)*F7/F6
      SOR=AMAX1(SOR1,SOR2)
   44 SOR1=SOR*F2*.5*DY(I)
      IF (-SOR*R2(I)-1.) 95,95,96
   95 SU(I)=SOR1
      SD(I)=0.
      GO TO 40
   96 FUB=AMAX1(0.,((RATIO1+RATIO2)*F3-RATIO2-RATIO3*F4)/RATIO2)
      IF (F2-FUB) 41,41,94
   94 DSDFU=SOR1/(F2-FUB)
      SU(I)=-DSDFU*FUB
      SD(I)=DSDFU
      GO TO 40
   41 SU(I)=0.
      SD(I)=0.
   40 SUFU(I)=SU(I)
      SDFU(I)=SD(I)
   90 CONTINUE
C     -------------------------------------- TEST 12
      IF(ITEST) 402,401,402
  402 LAB(1)=6HTEST 1
      LAB(2)=1H2
      WRITE(6,100) LAB
      LAB(1)=6HSD(I
      LAB(2)=1H)
      WRITE(6,100) LAB,(SD(I),I=1,NP3)
      LAB(1)=6HSU(I
      LAB(2)=1H)
      WRITE(6,100) LAB,(SU(I),I=1,NP3)
  401 CONTINUE
      GO TO 6000
C     ------------------------------------------ DX-FU*DXFU ----------
 2000 IF (NV.NE.JFUOX) GO TO 3000
      DO 50 I=2,NP2
      SU(I)=0.
   50 SD(I)=0.
      GO TO 6000
```

```
      C ---------------   SOURCE TERMS FOR CO   ----------------------------
 3000 IF (NV.NE.JCO) GO TO 3500
      F2=0.
      DO 140 I=2,NP2
      IF (INERT-1) 145,141,145
  145 F2=F(JFU,I)
      F3=F(JFUOX,I)
      F4=F(JCO,I)
      F6=F(JK,I)
      F7=F(JD,I)
      FS1=FS(JOX,I)
      FS2=FS(JT,I)
      IF (I-2) 142,146,142
  146 F2=F2+.25*(F(JFU,3)-F2)
      F3=F3+.25*(F(JFOX,3)-F3)
      F4=F4+.25*(F(JCO,3)-F4)
      F6=F6+.25*(F(JK,3)-F6)
      F7=F7+.25*(F(JD,3)-F7)
      FS1=FS1+.25*(FS(JOX,3)-FS1)
      FS2=FS2+.25*(FS(JT,3)-FS2)
  142 IF (I-NP2) 143,147,143
  147 F2=F2+.25*(F(JFU,NP1)-F2)
      F3=F3+.25*(F(JFUOX,NP1)-F3)
      F4=F4+.25*(F(JCO,NP1)-F4)
      F6=F6+.25*(F(JK,NP1)-F6)
      F7=F7+.25*(F(JD,NP1)-F7)
      FS1=FS1+.25*(FS(JOX,NP1)-FS1)
      FS2=FS2+.25*(FS(JT,NP1)-FS2)
  143 IF (F6) 141,141,1430
 1430 IF (FS1) 141,141,1431
 1431 SOR1=-PREXP2*RHO(I)**2*FS1*EXP(-ARCON2/FS2)
      GO TO (148,149), MODEO
  148 SOR=SOR1
      GO TO 144
  149 SOR2=-CR2*RHO(I)*F7/F6
      SOR=AMAX1(SOR1,SOR2)
  144 SOR1=SOR*F4*.5*RBY(I)
      IF (-SOR*DZ(I)-1.) 945,945,946
  945 SU(I)=SOR1-RATIO4*(SUFU(I)+SDFU(I)*F2)
      SD(I)=0.
      GO TO 140
  946 FUB=AMAX1(0.,((RATIO1+RATIO2)*F3-RATIO2-RATIO1*F2)/RATIO3)
      IF (F4-FUB) 141,141,944
  944 DSDCO=SOR1/(F4-FUB)
      SU(I)=-DSDCO*FUB-RATIO4*(SUFU(I)+SDFU(I)*F2)
      SD(I)=DSDCO
      GO TO 140
  141 SU(I)=-RATIO4*(SUFU(I)+SDFU(I)*F2)
      SD(I)=0.
  140 CONTINUE
      C ------------------------------------------------------------ TEST 13
      IF (ITEST) 178,179,178
  178 LAB(1)=6HTEST 1
      LAB(2)=6H3
      WRITE (6,100) LAB
      LAB(1)=6HSU(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(SU(I),I=1,NP3)
      LAB(1)=6HSD(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(SD(I),I=1,NP3)
  179 CONTINUE
      GO TO 5000
      C ---------------   SWIRL VELOCITY   ---------------------
 3500 IF (NV.NE.JVT) GO TO 4000
      DO 60 I=2,NP2
      SU(I)=0.0
   60 SD(I)=0.0
      GO TO 5000
      C ---------------   TURBULENT KINETIC ENERGY   --------------------
 4000 IF (NV.NE.JK) GO TO 5000
      D22=Y(3)-Y(1)
      VT2=F(JVT,2)/(.75*R(2)+.25*R(3))
      VT3=F(JVT,3)/R(3)
      RK2=SQRT(F(JK,2))
      RK3=SQRT(F(JK,3))
      DUDY(2)=(U(3)-U(2))/D22
```

```
      DVTDY=(VT3-VT2)/D22
      DK2=(RK3-RK2)/D22
      GENR(2)=DUDY(2)**2+(DVTDY-VT2/(.75*R(2)+.25*R(3)))**2
C     ------------------------------
      DO 73 I=3,NP1
      D11=D22
      D22=Y(I+1)-Y(I)
      IF (I.EQ.NP1) D22=Y(NP3)-Y(NP1)
      D12=D11+D22
      DUDY(I)=D11*(U(I+1)-U(I))/(D12*D22)+D22*(U(I)-U(I-1))/(D12*D11)
      VT1=VT2
      VT2=VT3
      VT3=F(JVT,I+1)/R(I+1)
      IF (I.EQ.NP1) VT3=F(JVT,NP2)/(.75*R(NP2)+.25*R(NP1))
      DVTDY=D11*(VT3-VT2)/(D12*D22)+D22*(VT2-VT1)/(D12*D11)
      RK1=RK2
      RK2=RK3
      RK3=SQRT(F(JK,I+1))
      DRKDY=D11*(RK3-RK2)/(D12*D22)+D22*(RK2-RK1)/(D12*D11)
      GENR(I)=DUDY(I)**2+(DVTDY-VT2/R(I))**2
      SU(I)=EMUT(I)*GENR(I)
   73 SD(I)=-(RHO(I)*F(JD,I)+2.*EMUL(I)*DRKDY**2)/F(JK,I)
C     ---------------------
      DUDY(NP2)=(U(NP2)-U(NP1))/D22
      DVTDY=(VT3-VT2)/D22
      DKNP2=(RK3-RK2)/D22
      GENR(NP2)=DUDY(NP2)**2+(DVTDY-VT3/(.75*R(NP2)+.25*R(NP1)))**2
      F6=.75*F(JK,2)+.25*F(JK,3)
      F7=.75*F(JD,2)+.25*F(JD,3)
      SU(2)=EMUT(2)*GENR(2)
      SD(2)=-(RHO(2)*F7+2.*EMUL(2)*DK2**2)/F6
      F6=.75*F(JK,NP2)+.25*F(JK,NP1)
      F7=.75*F(JD,NP2)+.25*F(JD,NP1)
      SU(NP2)=EMUT(NP2)*GENR(NP2)
      SD(NP2)=-(RHO(NP2)*F7+2.*EMUL(NP2)*DKNP2**2)/F6
   76 DO 77 I=2,NP2
      SU(I)=SU(I)*0.5*RDY(I)
   77 SD(I)=SD(I)*0.5*RDY(I)
C     --------------------------------------------------     TEST I3
      IF (ITEST) 78,79,78
   78 LAB(1)=6HTEST 1
      LAB(2)=6H)
      WRITE (6,100) LAB
      LAB(1)=6HSU(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(SU(I),I=1,NP3)
      LAB(1)=6HSD(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(SD(I),I=1,NP3)
   79 CONTINUE
C     ---------------------
      GO TO 6000
C     ---------------      TURBULENCE DISSIPATION      ----------------
 5000 IF (NW.NE.JD) GO TO 6000
      D22=Y(3)-Y(2)
      DO 80 I=3,NP1
      C2E=C2
      IF (ISOLVE(JVT).EQ.0) GO TO 90
      D11=D22
      D22=Y(I+1)-Y(I)
      D12=D11+D22
      DRVTDY=D11*(F(JVT,I+1)-F(JVT,I))/(D12*D22)+D22*(F(JVT,I)-F(JVT,I-1
     * ))/(D12*D11)
      C2E=C2E+C2VT*(F(JVT,I)/R(I)**3)*DRVTDY/(GENR(I)+1.0E-20)
      C2E=AMIN1(C2E,3.)
      C2E=AMAX1(C2E,1.)
   90 DUDYDY=(DUDY(I+1)-DUDY(I-1))/(Y(I+1)-Y(I-1))
      FACTOR=2.*EMUL(I)*EMUT(I)*DUDYDY*DUDYDY/RHO(I)
      SU(I)=C1*F(JD,I)*EMUT(I)*GENR(I)/F(JK,I)+FACTOR
   80 SD(I)=-C2E*F(JD,I)*RHO(I)/F(JK,I)
C     ------------------
      F6=.75*F(JK,2)+.25*F(JK,3)
      F7=.75*F(JD,2)+.25*F(JD,3)
      GO TO (81,82,82), KIN
   81 SU(2)=1.E30*CD75*F6**1.5/(YI*AX)
      SD(2)=-1.E30
      GO TO 83
```

```
      SUBROUTINE AUX          73/74    OPT=0 TRACE                          FTN 4.6+439         08/24/78  10.30.04         PAGE    5

        82 SU(2)=C1*F7*EMUT(2)*GENR(2)/F6                                                          AU      301
           SD(2)=-C2*F7*RHO(2)/F6                                                                  AU      302
        83 F6=.75*F(JK,NP2)+.25*F(JK,NP1)                                                          AU      303
           F7=.75*F(JB,NP2)+.25*F(JB,NP1)                                                          AU      304
           GO TO (84,85,85), KEX                                                                   AU      305
        84 SU(NP2)=1.E30*C875*F6**1.5/(YE*AK)                                                      AU      306
           SD(NP2)=-1.E30                                                                          AU      307
           GO TO 86                                                                                AU      308
        85 SU(NP2)=C1*F7*EMUT(NP2)*GENR(NP2)/F6                                                    AU      309
           SD(NP2)=-C2*F7*RHO(NP2)/F6                                                              AU      310
        86 DO 87 I=2,NP2                                                                           AU      311
           SU(I)=SU(I)*0.5*RDY(I)                                                                  AU      312
        87 SD(I)=SD(I)*0.5*RDY(I)                                                                  AU      313
C     -------------------------------------------------------------- TEST 14                       AU      314
           IF (ITEST) 88,89,88                                                                     AU      315
        88 LAB(1)=6HTEST I                                                                         AU      316
           LAB(2)=6H4                                                                              AU      317
           WRITE (6,100) LAB                                                                       AU      318
           LAB(1)=6HSU(I                                                                           AU      319
           LAB(2)=6H)                                                                              AU      320
           WRITE (6,100) LAB,(SU(I),I=1,NP3)                                                       AU      321
           LAB(1)=6HSD(I                                                                           AU      322
           LAB(2)=6H)                                                                              AU      323
           WRITE (6,100) LAB,(SD(I),I=1,NP3)                                                       AU      324
        89 CONTINUE                                                                                AU      325
C     ---------------                                                                              AU      326
      6000 CONTINUE                                                                                AU      327
           RETURN                                                                                  AU      328
       100 FORMAT(1H ,A6,A2,1P11E11.3/(9X,11E11.3))                                                AU      329
           END                                                                                     AU      330

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

    56       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   115       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   186       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   305       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   313       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
```

```
      SUBROUTINE STRIDE(ISW)
      COMMON/CDMA/A(43),AJE(7),AJI(7),B(43),C(43),CSALFA,D(43),DPDX(43),
     1 DZ,EMU(43),F(7,43),FS(5,43),IAC,IEND,IFIN,INDE(7),INDI(7),IOUT,
     2 ISTEP,ITEST,IUTRAP,J1,J5W,JE,JY,KEX,KIN,KRAD,N,NDZ,NF,NOVEL,NP1,
     3 NP2,NP3,OM(43),OMD(43),P(43),PEI,PR(7),PREF(7),PSIE,PSII,R(43),
     4 RHO(43),RME,RMI,RU(43),SD(43),SU(43),TAUE,TAUI,U(43),XD,XU,
     5 Y(43),YE,YI,PSUML(43),RDY(43),ISOLVE(7),US(43),AMU(43),
     5 DZ(43),DZOLD(43),ZUI,ZUE,ZDI,ZDE,DPDGX(43),
     6 JM,JFU,JFUDX,JCD,JUT,JE,JS,JDE,JT,JM2,JM2D,JCD2
C/---------------  SUBROUTINE FOR PROGRAM GENMIX 6A  ------------------
C/ THIS SUBROUTINE PERFORMS THE SAME OPERATIONS AS THE ONE IN GENMIX6A
C  BUT MORE ECONOMICALLY. THE A,B,C ARRAYS ARE ONE-DIMENSIONAL. SOME
C  OFTEN USED FUNCTIONS OF OM ARE STORED, AND A B ARRAY SAVES
C  UNNECESSARY ARITHMETIC IN THE TDMA OPERATION.
C-----------------------------------------------------------------------
      DIMENSION AMLPT(43),BOMT3(43),FDIFI(7),FDIFE(7),GE(7),GI(7)
      DIMENSION PBOM(43),PGOM(43),TMLPT(43),TIPP(7),TIFF(7),BOM(43)
      DIMENSION TMP3FF(7),OMPOM(43)
      DIMENSION PD4(43),PG34(43)
      DIMENSION IKAS(7)
      DATA IKAS/1,1,1,1,0,0,0/
C
      GO TO (1000,2000,3000,4000), ISW
C
C*********************************************  S T R I D E 1  ***************
 1000 IF(ISTEP) 1003,1003,1100
 1003 OMI=.5*OM(3)
      OME=.5*(1.-OM(NP1))
      DO 1002 I=2,NP2
      BOM(I)=OM(I+1)-OM(I-1)
      BOMT3(I)=3.*BOM(I)
      OMPOM(I)=OM(I)+OM(I+1)
 1002 OMD(I)=OM(I+1)-OM(I)
      OMD(1)=BOM(2)
      BPE=1.
      BPI=1.
      Y(1)=0.
      IF(KRAD.EQ.1) GO TO 1100
      DO 1001 I=1,NP3
 1001 R(I)=1.
      R25=1.
      RM15=1.
      IF(ITEST.NE.0) WRITE(6,9010) (R(I),I=1,NP3),R25,RM15
C-------------------------------  CALCULATION OF RHO*U 'S  ------------------
 1100 DO 1101 I=1,NP3
      IF(RHO(I).GT.0.) GO TO 1101
      WRITE(6,1108) RHO(I),I,RHO(I)
 1108 FORMAT(30H ********** NEGATIVE OR ZERO RHO(I)=,1PE11.3,6H AT I=,
     1 I3,6X,21HSET TO ABS OF RHO(I)=,E11.3,17H ******** STRIDE1)
      RHO(I)=ABS(RHO(I))
 1101 RU(I)=RHO(I)*U(I)
      RU3=RU(3)
      RUM1=RU(NP1)
      DO 1102 I=2,NP1
 1102 RU(I)=.5*(RU(I)+RU(I+1))
      IF(ITEST.NE.0) WRITE(6,9010) (RU(I),I=1,NP3),RUM1,RU3,PEI
C-------------------------------  CALCULATION OF Y 'S AND R 'S  --------------
C     ------------------------------------------  Y'S FOR PLANE GEOMETRY
      YI=PEI*OMI/(BPI*RU(2))
      Y(3)=YI+PEI*OM(3)/(RU(2)+RU3)
      Y(2)=2.*YI-Y(3)
      DO 1103 I=4,NP1
 1103 Y(I)=Y(I-1)+PEI*OMD(I-1)/RU(I-1)
      YM15=Y(NP1)+PEI*OMD(NP1)/(RU(NP1)+RUM1)
      YE=PEI*OME/(BPE*RU(NP1))
      Y(NP3)=YM15+YE
      Y(NP2)=2.*YM15-Y(NP1)
      IF(KRAD.EQ.0) RETURN
C     ----------------------------  Y'S AND R'S FOR AXISYMMETRICAL GEOMETRY
      IF(CSALFA.EQ.0.) GO TO 1119
C     ------------------------------------------  CSALFA NE ZERO
      COSD2=.5*CSALFA
      IF(R(1).NE.0.) GO TO 1105
C-----------------------------------------------  R(1)=0.
      DO 1106 I=2,NP3
      Y(I)=SQRT(ABS(Y(I)/COSD2))
 1106 R(I)=Y(I)*CSALFA
```

```
      VI=SQRT(ABS(VI/COSD2))
      VN15=SQRT(ABS(VN15/COSD2))
      GO TO 1107
C ------------------------------------------------------  R(I) NE 0.
 1105 R1D2=.5*R(1)
      R1D2SQ=R1D2*R1D2
      DO 1104 I=2,NP3
      V(I)=V(I)/(R1D2+SQRT(ABS(R1D2SQ+COSD2*V(I))))
 1104 R(I)=R(1)+V(I)*CSALFA
      VI=VI/(R1D2+SQRT(ABS(R1D2SQ+COSD2*VI)))
      VN15=VN15/(R1D2+SQRT(ABS(R1D2SQ+COSD2*VN15)))
 1107 R25=R(1)+VI*CSALFA
      RN15=R(1)+VN15*CSALFA
      VE=V(NP3)-VN15
      RETURN
C ------------------------------------------------------  CSALFA EQ ZERO
 1110 DO 1111 I=2,NP3
      V(I)=V(I)/R(1)
 1111 R(I)=R(1)
      VI=VI/R(1)
      VN15=VN15/R(1)
      R25=R(1)
      RN15=R(1)
      VE=V(NP3)-VN15
      RETURN
C**************************************  S T R I D E 2  ****************
C ---------------------------------------  PRELIMINARIES FOR COEFFICIENTS
 2000 DO 2010 I=2,NP2
 2010 PD4(I)=PEI/DZ(I)
      G=RRI-RNE
      ARRI=ABS(RRI)
      ARNE=ABS(RNE)
      GD4=.25*G
      RREDZ=.5*RRI
      DO 2004 I=2,NP2
      PDOM(I)=PD4(I)*DOM(I)
      PD4(I)=.25*PD4(I)
      PGD4(I)=PD4(I)*GD4
 2004 PGDM(I)=PGD4(I)*DMD(I)
      P4DMP=PD4(2)*DOM(2)
C ------------------------------------------------------  GRID POINT 2
C------------------------------------------------------  TAUI, BPI, TI
      IF(KIN.NE.1) GO TO 2001
      CALL WF(5,1,BPI,TI,TAUI)
      GO TO 2002
 2001 TI=0.
      IF(KRAD.EQ.0) BPI=.33333+.66667*RU(1)/RU(2)
      IF(KRAD.EQ.1) BPI=(R(1)*(5.*RU(1)+RU(2))+3.*R25*
     1                  (RU(1)+RU(2)))/6./(R(1)+R25)/RU(2)
 2002 DO 2700 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 2700
      IF (KIN.NE.1) GO TO 2705
      CALL WF (J,1,FDIFI(J),TIFF(J),GI(J))
      IF (INDI(J).EQ.2) GO TO 2700
      AJI(J)=GI(J)*(F(J,1)-.5*(F(J,2)+F(J,3))-FDIFI(J))
      GO TO 2700
 2705 TIFF(J)=0.
      FDIFI(J)=0.
 2700 CONTINUE
C ------------------------------------------------------  GRID POINT NP2
C------------------------------------------------------  TAUE, BPE, TNP3
 2304 IF(KEX.NE.1) GO TO 2003
      CALL WF(0,NP3,BPE,TNP3,TAUE)
      GO TO 2310
 2003 TNP3=0.
      IF(KRAD.EQ.0) BPE=.33333+.66667*RU(NP3)/RU(NP1)
      IF(KRAD.EQ.1) BPE=(R(NP3)*(5.*RU(NP3)+RU(NP1))+3.*RN15*
     1                  (RU(NP3)+RU(NP1)))/6./(R(NP3)+RN15)/RU(NP1)
 2310 DO 2720 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 2720
      IF (KEX.NE.1) GO TO 2730
      CALL WF(J,NP3,FDIFE(J),TNP3FF(J),GE(J))
      IF (INDE(J).EQ.2) GO TO 2720
      AJE(J)=GE(J)*(.5*(F(J,NP2)+F(J,NP1))+FDIFE(J)-F(J,NP3))
      GO TO 2720
 2730 TNP3FF(J)=0.
      FDIFE(J)=0.
```

```
 2720 CONTINUE
      RETURN
C*********************************** S T R I D E 3 ****************
 3000 CALL SOURCE(0)
C     --------------------- BOUNDARY COEFFICIENTS FOR VELOCITY
C     --------- GRID POINT 2 COEFFICIENTS  --------------
      HLP=RMID2-GD4*OMPOM(2)
      AHLP=ABS(HLP)
      THLP=HLP+HLP
      THLPT(2)=THLP
      TP=EM U(2)
      TTP=TP+AHLP+ABS(TP-AHLP)
      A(2)=TTP-THLP-T1-PGOM(2)
      B(2)=2.*T1+RMI+ARMI
      C(2)=P4OMP*(3.*U(2)+U(3))-US(2)
      D(2)=A(2)+B(2)+PBOM(2)
C     ------- GRID POINT NP2 COEFFICIENTS     ------------
      HLM=RMID2-GD4*OMPOM(NP1)
      AHLM=ABS(HLM)
      THLM=HLM+HLM
      THLPT(NP2)=THLM
      TM=EM U(NP1)
      TTM=TM+AHLM+ABS(TM-AHLM)
      P4OMM=PD4(NP2)*BOM(NP2)
      A(NP2)=2.*TMP3-RME+ARME
      B(NP2)=TTM+THLM-TMP3-PGOM(NP1)
      C(NP2)=P4OMM*(3.*U(NP2)+U(NP1))-US(NP2)
      D(NP2)=A(NP2)+B(NP2)+PBOM(NP2)
C     --------     MID-STREAM COEFFICIENTS    ----------
      DO 3005 I=3,NP1
      THLM=THLP
      HLP=RMID2-GD4*OMPOM(I)
      THLP=HLP+HLP
      THLPT(I)=THLP
      AHLP=ABS(HLP)
      AHLPT(I)=AHLP
      TTM=TTP
      TP=EM U(I)
      TTP=TP+AHLP+ABS(TP-AHLP)
      A(I)=TTP-THLP-PGOM(I)
      B(I)=TTM+THLM-PGOM(I-1)
      C(I)=PD4(I)*(BOMT3(I)*U(I)+OMD(I)*U(I+1)+OMD(I-1)*U(I-1))-US(I)
      D(I)=A(I)+B(I)+PBOM(I)
 3005 CONTINUE
      GO TO (3021,3020), NOVEL
 3020 IF(ITEST) 3900,3905,3900
 3900 WRITE(6,3901) (A(I),I=2,NP2)
      WRITE(6,3902) (B(I),I=2,NP2)
      WRITE(6,3903) (C(I),I=2,NP2)
      WRITE(6,3904) (D(I),I=2,NP2)
 3901 FORMAT(7H  A(I) ,1P11E11.3/(7X,11E11.3))
 3902 FORMAT(7H  B(I) ,1P11E11.3/(7X,11E11.3))
 3903 FORMAT(7H  C(I) ,1P11E11.3/(7X,11E11.3))
 3904 FORMAT(7H  C(I) ,1P11E11.3/(7X,11E11.3))
 3905 CONTINUE
C---------------------------------                 -------------------
      IF (KIN.EQ.2.AND.RU(1).NE.0.) U(1)=U(1)-DPDX(1)*DZ(1)/RU(1)
      IF (KEX.EQ.2.AND.RU(NP3).NE.0.) U(NP3)=U(NP3)-DPDX(NP3)*DZ(NP3)
     1 /RU(NP3)
C--------------------------------- SOLVE FOR DOWNSTREAM U 'S  ------------
      B(2)=(B(2)*U(1)+C(2))/D(2)
      A(2)=A(2)/D(2)
      DO 3048 I=3,NP2
      T=D(I)-B(I)*A(I-1)
      A(I)=A(I)/T
 3048 B(I)=(B(I)*B(I-1)+C(I))/T
      DO 3050 IDASH=2,NP2
      I=N+4-IDASH
      U(I)=A(I)*U(I+1)+B(I)
C     ------------------------------------ TEST FOR NEGATIVE U'S
C/IUTRAP=0,NO ACTION/ .GT.0,SET TO 1.E-30/ .GT.1,IFIN=-1/ .GT.2,ITEST=1/
      IF(IUTRAP.EQ.0.OR.I.EQ.2.OR.I.EQ.NP2) GO TO 3050
      IF(U(I)) 3046,3046,3050
 3046 J=ISTEP+1
      WRITE(6,3047) U(I),I,J
 3047 FORMAT(25H ********** U (LE ZERO) =,1PE10.3,6H AT I=,I3,
     1 8H, ISTEP=,I6,34H, SET U TO 1.E-30 ******** STRIDE3)
```

```
      U(I)=1.E-30
      IFIN=-IUTRAP/2
      ITEST=IUTRAP/3
 3050 CONTINUE
C ---------------------------------------------------------
      IF(KIN.EQ.3) U(1)=.5*(U(2)+U(3))
      IF(KEX.EQ.3)U(NP3)=.5*(U(NP1)+U(NP2))
 3021 IF (ITEST) 3011,3014,3011
 3011 WRITE(6,3012) (U(I),I=1,NP3)
 3012 FORMAT(3H U ,6X,1P11E11.3/(9X,11E11.3))
C ---------------------------------------------------------
C ------------------- SOLVE FOR DOWN STREAM F'S ------------
 3014 DO 3321 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 3321
      AKAS=FLOAT(IKAS(J))
C -------  COMPUTE SOURCE TERMS  ----------
      CALL SOURCE(J)
C -------  GRID POINT 2  ---------
      TP=EM U(2)
      TPF2=TP/PREF(J)
      THLP=THLPT(2)
      AHLP=.5*ABS(THLP)
      TTPF(J)=TPF2+AHLP+ABS(TPF2-AHLP)
      T1F=T1FF(J)
      IF (KIN.NE.1) GO TO 2302
      IF(INDI(J).EQ.2) GO TO 2303
CC -------------- EDGE VALUE SPECIFIED -------------
 2302 A(2)=TTPF(J)-THLP-T1F-(PGOM(2)-.5*SD(2))*AKAS
      B(2)=2.*T1F+RMI+ARMI
      D(2)=A(2)+B(2)+PBOM(2)-2.*SD(2)
      IF (J.NE.JVT) GO TO 510
      RP=.5*(R(2)+R(3))
      ATP=2.*(RP/R(3))**2
      AT1=(R(1)/RP)**2
      DTP=2.*(RP/(.75*R(2)+.25*R(3)))**2
      A(2)=TTPF(J)*ATP-THLP-T1F*AT1-(PGOM(2)-.5*SD(2))*AKAS
      TT=3.*PGOM(2)-1.5*SD(2)
      IF (IKAS(J).EQ.0) TT=4.*PGOM(2)-2.*SD(2)
      D(2)=TTPF(J)*DTP+T1F+THLP+TT
  510 T=-T1F*FDIFI(J)
      GO TO 2305
C ---------------- EDGE FLUX SPECIFIED ------------
 2303 A(2)=TTPF(J)-THLP-(PGOM(2)-.5*SD(2))*AKAS
      B(2)=0.
      D(2)=A(2)+PBOM(2)-2.*SD(2)+RMI*2.
      T=RMI*F(J,1)+AJI(J)*R(I)
 2305 TT=3.*F(J,2)+F(J,3)
      IF (IKAS(J).EQ.0) TT=4.*F(J,2)
      C(2)=PGOMP*TT+2.*(T+SU(2))
 2300 CONTINUE
C -------  GRID POINT NP2  --------
      TM=EM U(NP1)
      TMF=TM/PREF(J)
      THLM=THLPT(NP2)
      AHLM=.5*ABS(THLM)
      TTMF=TMF+AHLM+ABS(TMF-AHLM)
      TMP3F=TMP3FF(J)
      IF (KEX.NE.1) GO TO 2312
      IF(INDE(J).EQ.2) GO TO 2313
C ---------------- EDGE VALUE SPECIFIED --------
 2312 A(NP2)=2.*TMP3F-RME+ARME
      B(NP2)=TTMF+THLM-TMP3F-(PGOM(NP1)-.5*SD(NP2))*AKAS
      D(NP2)=A(NP2)+B(NP2)+PBOM(NP2)-2.*SD(NP2)
      IF (J.NE.JVT) GO TO 520
      RM=.5*(R(NP2)+R(NP1))
      BTM=2.*(RM/R(NP1))**2
      BTMP3=(R(NP3)/RM)**2
      DTM=2.*(RM/(.75*R(NP2)+.25*R(NP1)))**2
      B(NP2)=TTMF*BTM+THLM-TMP3F*BTMP3-(PGOM(NP1)-.5*SD(NP2))*AKAS
      TT=3.*PGOM(NP1)-1.5*SD(NP2)
      IF (IKAS(J).EQ.0) TT=4.*PGOM(NP1)-2.*SD(NP2)
      D(NP2)=TTMF*DTM+TMP3F-THLM+TT
  520 T=-TMP3F*FDIFE(J)
      GO TO 2315
C ---------- EDGE FLUX SPECIFIED ---------
 2313 A(NP2)=0.
      B(NP2)=TTMF+THLM-(PGOM(NP1)-.5*SD(NP2))*AKAS
```

```
      D(NP2)=B(NP2)+PBOM(NP2)-2.*TD(NP2)-RME*2.
      T=-RME*F(J,NP3)-AJE(J)*D(NP3)
 2315 TT=2.*F(J,NP2)-F(J,NP1)
      IF (IKAS(J).EQ.0) TT=4.*F(J,NP2)
      C(NP2)=PBOMP*TT+2.*T*SU(NP2))
 2320 CONTINUE
C -------   MID-STREAM COEFFICIENTS   ---------
      DO 3002 I=3,NP1
      TTMF=TTPF(J)
      TPF=EM U(I)/PREF(J)
      TTPF(J)=TPF+AHLPT(I)+ABS(TPF-AHLPT(I))
      IF (J.EQ.JVT) GO TO 3015
      A(I)=TTPF(J)-THLPT(I)-PGOM(I)*AKAS
      B(I)=TTMF+THLPT(I-1)-PGOM(I-1)*AKAS
      D(I)=A(I)+B(I)+PBOM(I)-2.*TD(I)
      GO TO 2999
C     -----------
 3015 RP=.5*(R(I)+R(I+1))
      RM=.5*(R(I)+R(I-1))
      RMM=R(I-1)
      IF (I.EQ.3) RMM=.75*R(2)+.25*R(3)
      RPP=R(I+1)
      IF (I.EQ.NP2) RPP=.75*R(NP2)+.25*R(NP1)
      ATP=2.*(RP/RP2)**2
      BTM=2.*(RM/RM1)**2
      DTP=2.*(RP/R(I))**2
      DTM=2.*(RM/R(I))**2
      A(I)=TTPF(J)*ATP-THLPT(I)-PGOM(I)*AKAS
      B(I)=TTMF*BTM+THLPT(I-1)-PGOM(I-1)*AKAS
      TT=PGD4(I)*BOMT3(I)
      IF (IKAS(J).EQ.0) TT=4.*PGD4(I)*BOM(I)
      D(I)=TTPF(J)*DTP+TTMF*DTM+THLPT(I)-THLPT(I-1)+TT-2.*SD(I)
 2999 TT=BOMT3(I)*F(J,I)+OMD(I)*F(J,I+1)+OMD(I-1)*F(J,I-1)
      IF (IKAS(J).EQ.0) TT=4.*BOM(I)*F(J,I)
 3002 C(I)=PBOM(I)*TT+2.*SU(I)
      IF(ITEST) 3906,3907,3906
 3906 WRITE(6,3901) (A(I),I=2,NP2)
      WRITE(6,3902) (B(I),I=2,NP2)
      WRITE(6,3903) (C(I),I=2,NP2)
      WRITE(6,3904) (D(I),I=2,NP2)
 3907 CONTINUE
C     ----------------------------------------
      B(2)=(B(2)*F(J,1)+C(2))/D(2)
      A(2)=A(2)/D(2)
      DO 3148 I=3,NP2
      T=D(I)-B(I)*A(I-1)
      A(I)=A(I)/T
 3148 B(I)=(B(I)*B(I-1)+C(I))/T
      DO 3150 IDASH=2,NP2
      I=N+4-IDASH
 3150 F(J,I)=A(I)*F(J,I+1)+B(I)
C---------------------------   ADJUST F(J,1) AND F(J,NP3)   -----------
      GO TO (3210,3220,3230),KIN
 3210 IF(INDI(J).EQ.2) F(J,1)=FDEFI(J)+.5*(F(J,2)+F(J,3))+AJI(J)/GI(J)
      GO TO 3220
 3230 F(J,1)=.5*(F(J,2)+F(J,3))
 3220 GO TO (3310,3320,3330),KEX
 3310 IF(INDE(J).EQ.2) F(J,NP3)=FD(FE(J)+.5*(F(J,NP2)+
     1                          F(J,NP1))-AJE(J)/GE(J))
      GO TO 3320
 3330 F(J,NP3)=.5*(F(J,NP1)+F(J,NP2))
 3320 IF(ITEST) 3322,3321,3322
 3322 WRITE(6,3323) J,(F(J,I),I=1,NP3)
 3323 FORMAT(5H F, J=,I3,1P11E11.3/(9X,11E11.3))
 3321 CONTINUE
C     ----------------------------------------
 3060 ZUI=Z(3)
      ZUE=Z(N)
      PSII=PSII-RMI*DZ(1)
      PSIE=PSIE-RME*DZ(NP3)
      PEI=PSIE-PSII
      ISTEP=ISTEP+1
      RETURN
C**************************  S T R I D E 4  ****************************
 4000 CONTINUE
      NP2=N+2
      NP1=N+1
```

```
      NP2=N+2                                                    ST
      NP3=N+3                                                    ST
      DM(1)=0.                                                   ST
      DM(NP3)=1.                                                 ST
      ISTEP=0                                                    ST
      IEND=10000                                                 ST
      IAX=10000                                                  ST
      IOUT=10000                                                 ST
      DO 4010 I=1,NP3                                            ST
 4010 DZ(I)=0.                                                   ST
      IFIN=0                                                     ST
      KIN=1                                                      ST
      KEX=1                                                      ST
      RETURN                                                     ST
 9010 FORMAT(1H ,1P11E11.3)                                      ST
      END                                                        ST
```

CARD NR.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
199	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
361	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
365	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.

```
      SUBROUTINE WF(J,I5,OUT1,OUT2,OUT3)
      COMMON/COMA/A(43),AJE(7),AJI(7),B(43),C(43),CSALFA,D(43),EPDX(43),
     1 DX,EMU(43),F(7,43),FS(5,43),TAX,IEND,IFIN,INDE(7),INDI(7),IOUT,
     2 ISTEP,ITEST,IUTRAP,JS,JSW,JV,J?,KEX,KIN,KRAD,N,NDF,NF,NOVEL,NP1,
     3 NP2,NP3,OM(43),OMD(43),P(43),PEI,PR(7),PREF(7),PSIE,PSII,R(43),
     4 RHO(43),RME,RMI,RU(43),SD(43),SU(43),TAGE,TAUI,U(43),XD,XU,
     5 Y(43),YE,YI,PSURC(43),RDY(43),ISOLVE(7),ZS(43),AMU(43),
     5 DZ(43),DZOLD(43),ZUI,ZUE,ZDI,ZDE,DPADX(43),
     6 JH,JFU,JFOOX,JCD,JVT,JK,JD,JOX,JT,JH2,JH2O,JCO2
      COMMON/COMB/AK,ALMG,EWALL,G,H,HFU,INJECT,MASSTR,MODEL,PRESS,
     1 UGAS,WFAC,C1,C2,CD,C2UT,AKFAC,ALFAC,ARCON1,ARCON2,PREXP1,CB75,
     2 PREXP2,CR1,CR2,PODER,PODCP,RATIO1,RATIO2,RATIO3,RSTIO4
C/------- SUBROUTINE FOR PROGRAM GENMIX 4A
C/---------------- D.B.SPALDING, IMPERIAL COLLEGE, 1972 -------------
C
C     EFFECTS OF PRESSURE GRADIENT AND MASS TRANSFER ARE INCLUDED
C     EFFECTS OF RADIUS VARIATION ARE NEGLECTED
C     FOR VELOCITY,     OUT1=BP,    OUT2=T,  OUT3=TAU
C     FOR F'S,          OUT1=FIDIF, OUT2=T,  OUT3=G
C
      DATA SHALF/.04/, BPLAST/.9/
      INT=1/I1
      I2=I1-1+2*INT
      I3=I1-2+4*INT
      I25=I3-INT
      IF(J) 100,190,200
C ---------------------------------------------------- VELOCITY
  100 UREF=.5*(U(I2)+U(I3))
      RHOREF=.5*RHO(I1)+.25*(RHO(I2)+RHO(I3))
      RUREF=RHOREF*UREF
      RREF=.5*(R(I2)+R(I3))
      VREF=EMU(I1)
      YREF=YI+(YE-YI)*OM(I1)
      RE=UREF*RHOREF*YREF/VREF
      RRUREF=RREF*RUREF
      AM=(RMI-(RME+RMI)*OM(I1))/RRUREF
      EF=YREF*DPDX(I1)/RUREF/UREF
      IF(MODEL.EQ.1) GO TO 110
      IF(RE.LT.132.25) GO TO 110
C-----------------------------------------------------EXTENDED LOG LAW
      ER=RE*EWALL
      NIT=0
  101 SHALF1=SHALF
      S=SHALF**2
      SLOC=S+AM+EF
      IF(SLOC.GT.0.) GO TO 104
      SLOC=1.E-30
      SHALF=SQRT(ABS(AM+EF))
  104 BEE=SQRT(SLOC)/AK
      ARG=ER*(SHALF+(AM/(1.+BEE)+.5*EF)/SHALF)
      IF(ARG.GT.11.5*EWALL) GO TO 106
      GO TO 110
  106 SHALF=AK/ALOG(ARG)
      IF(ABS(SHALF-SHALF1).LT..0001.OR.NIT.GT.10) GO TO 102
      NIT=NIT+1
      GO TO 101
  102 S=SHALF**2
      SAT=.5*(SHALF**2+SLOC)
      OUT1=1./(1.+BCE)
      EM U(I25)=.25*RHOREF*RREF*ABS(U(I3)-U(I2))*(AK/OUT1)**2
      GO TO 103
C ------------------------------------------------- LAMINAR FLOW
  110 AMRE=AM*RE
      FRE=EF*RE
      IF(ABS(AMRE).LT..01) GO TO 111
      AMRE=AMAX1(-60.,AMIN1(60.,AMRE))
      EXPMRE=EXP(AMRE)
      STORE=EXPMRE-1.-AMRE
      AMRESQ=AMRE*AMRE
      SRE=AMRE*([illegible].-STORE*FRE/AMRESQ)/(EXPMRE-1.)
      OUT1=SRE*STORE/AMRESQ+FRE*(STORE-.5*AMRESQ)/(AMRESQ*AMRE)
      GO TO 112
  111 SRE=(2.-FRE*(1.+AMRE/3.))/(2.+AMRE)
      OUT1=SRE*(.5+AMRE/6.)+FRE*(.16667+AMRE/24.)
  112 IF(SRE.GT.1.E-30) GO TO 113
      SRE=1.E-30
      OUT1=.33333
```

```
  113 S=SRE/RE
      EK=U(I2+1)-UREF*RREF/ABS(Y(I3)-Y(I2))
  103 OUT2=S*RR*CREF
      OUT3=OUT2*UREF/R(I1)
C     ---------- UNDER-RELAX OUT1.
      OUT1=.1*OUT1+.9*EPLAST
      EPLAST=OUT1
      RETURN
C-------------------- STAGNATION ENTHALPY, FUEL, OX-FU/OXDFU
  200 IF(RE.LT.132.25) GO TO 210
      IF(MODEL.EQ.1) GO TO 210
      IF (SRE.LE.11.5*EWALL) GO TO 210
      PRRAT=PR(J)/PREF(J)
      PJAY=9.*(PRRAT-1.)/PRRAT**.25
      S=SAV/PREF(J)/(1.+AMAX1(-.99999,PJAY*SQRT(ABS(SAV))))
      OUT1=0.
      IF (J.EQ.JH) OUT1=(M-1.)*.5*UREF**2
      OUT2=S*RR*UREF
      IF (J.EQ.JK) OUT2=0.
      OUT3=OUT2/R(I1)
      RETURN
  210 IF(ABS(AMPE).LT..01) GO TO 211
      S=AMS/(EXP(PR(J)*AMPE)-1.)
      GO TO 212
  211 S=1./PR(J)/RE/(1.+.5*PR(J)*AMPE)
  212 OUT1=0.
      IF (J.EQ.JH) OUT1=(PR(J)-1.)*.5*UREF**2
      OUT2=S*RRDREF
      IF (J.EQ.JK) OUT2=0.
      OUT3=OUT2/R(I1)
      RETURN
      END
```

```
      SUBROUTINE PLOTS (X,IDIM,IMAX,XAXIS,Y,JDIM,JMAX,YAXES,SYMBOL)
C*****16.8.72*****************************************************
C                                                                *
C   SUBROUTINE FOR PLOTTING J CURVES OF Y(J,I) AGAINST X(I).
C                                                                *
C   X AND Y ARE ASSUMED TO BE IN ANY RANGE EXCEPT THAT NEGATIVE VALUES *
C    ARE PLOTTED AS ZERO.                                        *
C   X AND Y ARE SCALED TO THE RANGE 0. TO 1. BY DIVISION BY THE MAXIMA, *
C    WHICH ARE ALSO PRINTED.                                     *
C   IDIM IS THE VARIABLE DIMENSION FOR X.                        *
C   IMAX IS THE NUMBER OF X VALUES.                              *
C   XAXIS STORES THE NAME OF THE X-AXIS.                         *
C   JDIM IS THE VARIABLE DIMENSION FOR Y.                        *
C   JMAX IS THE NUMBER OF CURVES TO BE PLOTTED, (UP TO 10).      *
C   THE ARRAY YAXES(J) STORES THE NAMES OF THE CURVES.           *
C   THE ARRAY SYMBOL(J) STORES THE SINGLE CHARACTERS USED FOR PLOTTING. *
C                                                                *
C*****************************************************************
      DIMENSION X(IDIM),Y(JDIM,IDIM),YAXES(JDIM,2),SYMBOL(JDIM),
     1 A(101),YMAX(10)
      DATA  DOT,CROSS,BLANK/1H.,1H+,1H /
C*****  SCALING X ARRAY TO THE RANGE 0 TO 50
      XMAX=1.E-30
      DO 1 I=1,IMAX
    1 IF(X(I).GT.XMAX) XMAX=X(I)
      DO 2 I=1,IMAX
      X(I)=X(I)/XMAX*50.
    2 IF(X(I).LT.0.) X(I)=0.
C*****  SCALING Y ARRAY TO THE RANGE 0 TO 100
      DO 3 J=1,JMAX
      YMAX(J)=1.E-30
      DO 4 I=1,IMAX
    4 IF(Y(J,I).GT.YMAX(J)) YMAX(J)=Y(J,I)
      DO 3 I=1,IMAX
      Y(J,I)=Y(J,I)/YMAX(J)*100.
    3 IF(Y(J,I).LT.0.) Y(J,I)=0.
C*****  IDENTIFYING THE VARIOUS CURVES TO BE PLOTTED
      WRITE(6,103) XAXIS,XMAX
      WRITE(6,100)((YAXES(I,J),J=1,2),I=1,JMAX)
      WRITE(6,106) (SYMBOL(I),I=1,JMAX)
      WRITE(6,107) (YMAX(I),I=1,JMAX)
      DO 5 I=1,11
    5 A(I)=0.1*FLOAT(I-1)
      WRITE(6,101) (A(I),I=1,11)
C*****  MAIN LOOP.  EACH PASS PRODUCES AN X-CONSTANT LINE.
      DO 40 I=1,51
      IF(I.EQ.1.OR.I.EQ.51) GO TO 32
      GO TO 33
C*****  ALLOCATE . OR + AS MARKER ON THE Y-AXIS
   32 DO 30 K=1,101
   30 A(K)=DOT
      DO 31 K=11,101,10
   31 A(K)=CROSS
C*****  ALLOCATE . OR + MARK ON THE X-AXIS, ALSO THE APPROPRIATE X VALUE
   33 A(1)=DOT
      A(101)=DOT
      K=I-1
   46 K=K-5
      IF(K)48,47,46
   47 A(1)=CROSS
      A(101)=CROSS
   48 XL=0.02*FLOAT(I-1)
C*****  CHECK IF ANY Y( X(I) ) VALUE LIES ON THIS X-CONSTANT LINE
C*****  IF YES GO TO 41, OTHERWISE GO TO 42
      DO 43 K=1,IMAX
      IF(IFIX(X(K)+1.5)-I) 43,41,43
C*****  LOCATE  Y(  X(I)  )
   41 DO 44 J=1,JMAX
      NY=Y(J,K)+1.5
      A(NY)=SYMBOL(J)
   44 CONTINUE
      GO TO 42
   43 CONTINUE
C*****  PRINT X-CONSTANT LINE
   42 WRITE(6,105) XL,(A(K),K=1,101),XL
C*****  PUTTING BLANKS INTO X-CONSTANT LINE
      DO 49 K=1,101
```

```
SUBROUTINE PLOTS      73/74    OPT=0 TRACE                FTN 4.6+439        08/24/78  10.30.04        PAGE    2

         49 A(K)=BLANK                                                           PL      79
         48 CONTINUE                                                             PL      80
            DO 50 I=1,11                                                         PL      81
         50 A(I)=.1*FLOAT(I-1)                                                   PL      82
            WRITE(6,104) (A(I),I=1,11)                                           PL      83
            RETURN                                                               PL      84
        100 FORMAT(11K Y-AXES ARE,5X,10(1X,A6,A4))                               PL      85
        101 FORMAT(1H0,2X,11F10.1)                                               PL      86
        102 FORMAT(15H MAXIMUM VALUES,1P10E11.3)                                 PL      87
        103 FORMAT(11H0X-AXIS IS ,A6,17H ,MAXIMUM VALUE =,1PE10.3)               PL      88
        104 FORMAT (3X,11F10.1)                                                  PL      89
        105 FORMAT(2H X,F6.2,3X,101A1,F6.2)                                      PL      90
        106 FORMAT(7H SYMBOL,11X,10(1X,A10))                                     PL      91
            END                                                                  PL      92
```

APPENDIX F

LISTING OF EMISSIONS MODEL

```
PROGRAM MAIN      73/74   OPT=0 TRACE                    FTN 4.6+439        03/24/78  14.42.35        PAGE    1

      PROGRAM MAIN (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE4)          MA        2
C                                                                         MA        3
C     *************************************************************      MA        4
C     *************************************************************      MA        5
C     ***************** COMBUSTOR DESIGN CRITERA ********************     MA        6
C     EMISSIONS MODEL                                                     MA        7
C                                                                         MA        8
C                                                                         MA        9
C     -------------------------------------------------------------      MA       10
CHAPTER0000000000000000000 PRELIMINARIES  000000000000000000000000000000 MA       11
C     ----------------------------- DIMENSIONS AND COMMON BLOCKS.         MA       12
      COMMON/COMA/A(43),AJE(15),AJI(15),B(43),C(43),CSALFA,D(43),         COMA      2
     1 DPDX(43),DX,EPU(43),F(15,43),FS(3,43),IAX,IEND,IFIN,INDE(15),      COMA      3
     2 INDI(15),IOUT,ISTEP,ITEST,IUTRAP,JS,JSN,JU,JY,KEX,KIN,KRAD,M,      COMA      4
     3 MO2,MF,MODEL,MP1,MP2,MP3,OM(43),OMD(43),P(43),PEI,PD(15),          COMA      5
     4 PREF(15),PSIE,PSII,R(43),RHO(43),RU(43),RME,RMI,SD(43),SU(43),     COMA      6
     5 TAUE,TAUI,U(43),XD,XU,Y(43),YE,YI,PSMPL(43),RSY(43),ISOLVE(15),     COMA      7
     6 US(43),AMU(43),SUM1,SUM2,SUM3,SUM4,PDGSCN,FDIFI(15),FDIFE(15),     COMA      8
     7 SE(15),SI(15),JLOC(12),W(12),JN,JFU,JCO2,JCO,JO2,JH2O,JOH,JO,JH5,  COMA      9
     8 JH2,JN,JNO,JM2,JVT,JD,JK,JT,JRV,NSP,NSPP,ABSOR,SCATR,BOM(200),     COMA     10
     9 TERM1,TERM2,ISMAX,EFU,EO2,EH2O,EPO,EPO                            COMA     11
      COMMON/COMB/AK,ALMG,EWALL,FD,H,HFU,INERT,MASSTR,MODEL,PRESS,        COMB      2
     1 UBAR,UFAC,C1,C2,C3,C2VT,AKFAC,ALFAC,ARCOM1,ARCOM2,PREXP1,CD75,     COMB      3
     2 PREXP2,CR1,CR2,MODER,MODCP,RATIO1,RATIO2,RATIO3,RATIO4,RATIO5,     COMB      4
     3 CX,MT,DEOLD,WFU,WCO2,WCO,WO2,WH2O,WOH,WO,WH,                        COMB      5
     4 WH2,WN,WNO,WN2                                                     COMB      6
      COMMON/COMC/ABI(43),APE(43),XM(40),NBP                              COMC      2
      COMMON/COMD/XJINJ(12),UINJ(12),YUINJ(12),VTUINJ(12),AUINJ(12),      COMD      2
     1 FVINJ(12),UVINJ(12),VINJ(12),VTVINJ(12),TVINJ(12),AVINJ(12),       COMD      3
     2 RUINJ(12),APUINJ(12),HUINJ(12),XLUINJ(12),TAN(2),DELA(2),          COMD      4
     3 PRAD(2),MUI,MUE,MVI,MVE                                            COMD      5
      DIMENSION TITLE(24),OUT(43),LAB(2)                                  MA       17
      DIMENSION XPLOT(43),YPLOT(10,43),TAXES(10,2),SYMBOL(10)             MA       18
      DIMENSION FLUX(15),DFI(15),DFE(15),AJIO(15),AJEO(15)                MA       19
      DIMENSION VIN(40),UIN(40),VTIN(40),TIN(40),MFUIN(40),MCOIN(40)      MA       20
      DIMENSION TKIN(40),TLIN(40),MCO2IN(40),MH2IN(40)                    MA       21
      DIMENSION MH2OIN(40),MO2IN(40)                                      MA       22
      DIMENSION IPLOT(10),IPRNT(10),SYM(10),LAB1(10),LAB2(10)             MA       23
      REAL MFUIN,MCOIN,MCO2IN,LAB,LAB1,LAB2,MH2IN,MH2OIN,MO2IN            MA       24
      NAMELIST/INPUT/IUTRAP,ULIM,RELLIM,AFAC,AERDLM,POWER,MODEL,          MA       25
     1 ARCOM1,PREXP1,CR1,ARCOM2,PREXP2,CR2,CP,IOPOX,C1,C2,C3,             MA       26
     2 C2VT,AKFAC,ALFAC,PREF,CX,MT,HFU,MODER,ITMIN,KREAD,UBAT,            MA       27
     3 TERM1,TERM2,ISMAX,EFU,EO2,EH2O,EPO,EPO                            MA       28
      DATA JN,JFU,JCO2,JCO,JO2,JH2O,JOH,JO,JH5/1,2,3,4,5,6,7,8,9/         MA       29
      DATA JH2,JN,JNO,JVT,JK,JD,JM2,JT,JRV/10,11,12,13,14,15,1,2,3/       MA       30
      DATA IPLOT/0,1,0,1,1,0,0,0,0,0,0,0,1,0,0,0,1,0/                     MA       31
      DATA SYM/1HF,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H+,1H*,           MA       32
     1 1HY,1H0,1H*,1H.,1HT,1HD/                                           MA       33
      DATA LAB1/5HPATH  ,6HFUEL  ,6HCO2   ,5HCO   ,6HOXYGEN,6HH2O         MA       34
     1 5HOH   ,6HO    ,6HH    ,6HH2   ,6HN    ,6HNO    ,5HUT              MA       35
     2 6HF    ,5HLEN  ,5HN2   ,5HTEMP ,5HRAD  /                           MA       36
      DATA LAB2/10H2   /                                                  MA       37
      DATA W/16.,44.,28.,32.,18.,17.,16.,1.,2.,14.,30.,28./               MA       38
      DATA WFU,WCO2,WCO,WO2,WH2O,WOH,WO,WH,WH2,WN,WNO,WN2/16.,44.,28.,    MA       39
     1 32.,18.,17.,16.,1.,2.,14.,30.,28./                                 MA       40
      DATA SUM1,SUM2,SUM3,SUM4/0.,0.,0.,0./                               MA       41
C                                                                         MA       42
      READ(5,1) TITLE                                                     MA       43
    1 FORMAT(12A6)                                                        MA       44
C                                                                         MA       45
C     -------------------------------------------------------------      MA       46
CHAPTERIIIIIIIIIIIIIIIIIII  PARAMETERS AND CONTROL INDICES  IIIIIIIIIIIII MA       47
      READ (5,2) M,KRAD,MASSTR,ISMPL,MODEL,INERT,IFLUX,ITERP              MA       48
    2 FORMAT (8(I2,8X))                                                   MA       49
      READ (5,3) NSTAT,NPROF,NPLOT,ITEST,LASTEP                           MA       50
    3 FORMAT (8(I5,5X))                                                   MA       51
      IUTRAP=2                                                            MA       52
      ULIM=.05                                                            MA       53
      RELLIM=.01                                                          MA       54
      AFAC=.2                                                             MA       55
      AERDLM=.02                                                          MA       56
      CSALFA=1.                                                           MA       57
      IOPOX=1                                                             MA       58
      H=.9                                                                MA       59
      AK=.435                                                             MA       60
      ALMG=.09                                                            MA       61
      FD=.333                                                             MA       62
```

```
      UFAC=.01
      NOVEL=2
      ITMIN=1
      NREAD=0
      URAT=.03
      TERR1=.1
      TERR2=1.E-4
      EFU=1.0
       EO2=.5
      EN2O=.5
      ERD=2.0
      EPR=0.
      ISMAX=500
C
C ---------------------------------------------------------------------------
CHAPTER2222222222222222222222222  GRID AND GEOMETRY  2222222222222222222
      READ (5,4) XU,XULAST,FRA,IEND,IOUT,PRESS,POWER
      READ (5,2) NBP
      READ (5,4) (XR(I),ARI(I),ARE(I),I=1,NBP)
      RI=TAB(XU,XR,ARI,NBP)
      RE=TAB(XU,XR,ARE,NBP)
      READ (5,4) RA,RB,RD
    4 FORMAT (8E10.4)
C     ------ R(I) ADJUSTMENT MADE JUST BEFORE CALL STRIDE(1).
C     -----------STRIDE4-----------STRIDE4-----------STRIDE4----------STRIDE4
      CALL STRIDE(4)
      IF(IEND.EQ.0.) IEND=0
      IF(IOUT.EQ.0.) IOUT=0
C     ------------------------ CHANGE IEND, IAX AND IOUT, IF NECESSARY.
      DO 20 I=2,NP2
   20 OUT(I)=(FLOAT(I-2)/FLOAT(N))**ABS(POWER)
      IF (POWER.GT.0.0) GO TO 22
      DO 24 I=2,NP2
      II=NP2+2-I
   24 Y(II)=1.0-OUT(I)
      GO TO 26
   22 DO 28 I=2,NP2
   28 Y(I)=OUT(I)
   26  CONTINUE
C
C ---------------------------------------------------------------------------
CHAPTER3333333333333333333333333  DEPENDENT VARIABLES SELECTION  33333353
C
      ISOLVE(JH)=ITEMP
      ISOLVE(JFU)=MASSTR
      ISOLVE(JCO2)=MASSTR
      ISOLVE(JCO)=MASSTR
      ISOLVE(JOX)=MASSTR
      ISOLVE(JH2O)=MASSTR
      ISOLVE(JOH)=MASSTR
      ISOLVE(JO)=MASSTR
      ISOLVE(JHS)=MASSTR
      ISOLVE(JH2)=MASSTR
      ISOLVE(JN)=MASSTR
      ISOLVE(JNO)=MASSTR
      ISOLVE(JUT)=ISWRL
      ISOLVE(JK)=MODEL-1
      ISOLVE(JD)=MODEL-1
      NF=15
      NFS=3
      IPRNT(JH)=0
      IPRNT(JFU)=MASSTR
      IPRNT(JCO)=MASSTR
      IPRNT(JUT)=ISWRL
      IPRNT(JK)=MODEL-1
      IPRNT(JD)=MODEL-1
      IPRNT(JCO2)=MASSTR
      IPRNT(JOX)=MASSTR
      IPRNT(JH2O)=MASSTR
      IPRNT(JOH)=MASSTR
      IPRNT(JO)=MASSTR
      IPRNT(JHS)=MASSTR
      IPRNT(JH2)=MASSTR
      IPRNT(JN)=MASSTR
      IPRNT(JNO)=MASSTR
      INDF=NF
      IPRNT(JH2+INDF)=MASSTR
```

```
      IPRNT(JT+INDX)=ITEMP
      IPRNT(JPV+INDX)=6
      NSP=12
      NSPM=NSP-1
      JLOC(1)=JFU
      JLOC(2)=JCO2
      JLOC(3)=JCO
      JLOC(4)=JOX
      JLOC(5)=JH2O
      JLOC(6)=JOH
      JLOC(7)=JO
      JLOC(8)=JHS
      JLOC(9)=JH2
      JLOC(10)=JN
      JLOC(11)=JNO
      JLOC(12)=JN2
C
C ----------------------------------------------------------------------
CHAPTER4444444444444444444444444444  MATERIAL CONSTANTS  444444444444444
C                                      S.I. UNITS
      GASCON=8314.
      WMIX=28.84
      CP=1049.
      CX=1.0
      HY=4.
      HFU=-49317.
C     ---ARRCON IS ACTIVATION ENERGY DIVIDED BY UNIVERSAL GAS CONSTANT.
      PREXP1=5.E+15
      ARCON1=28590.
      CPI=6.0
C
      DO 40 J=1,NF
      PR(J)=.7
      PREF(J)=.90
   40 IF (MODEL.EQ.1) PREF(J)=PR(J)
      PREF(JKT)=1.0
C  -----   TURBULENCE CONSTANTS     ------ ----
      C1=1.42
      C2=1.92
      CD=.09
      AMFAC=.03
      ALFAC=.02
      C2VT=0.36
      PREF(JK)=1.0
C  ---------      NAMELIST     -------
      READ (5,INPUT)
      PREF(JD)=AK**2/(C2-C1)/SQRT(CD)
      CD75=CD**.75
      GAMMA=CP/(CP-GASCON/WMIX)
      RHOSCN=PRESS*WMIX/GASCON
      WFU=12.*CX+HY
      W(1)=WFU
      RATIO1=WOX*(CX+HY/4.)/WFU
      RATIO2=.232
      SLN=1./(1.-URAT)-1.
      DUM=COEF(WFU,1)
      DUM=COEF(WFU,1)
C
C ----------------------------------------------------------------------
CHAPTER5555555555555555555555555555555555  INITIAL CONDITIONS  5555555555
      READ (5,4) UA,UD,VTA,VTD
      READ (5,4) F2A,F2D,TA,TD,TWALL
C
      F1A=F2A*HOR(TA,1)+(1.-F2A)*RATIO2*HOR(TA,4)+(1.-F2A)*(1.-RATIO2)*
     1    HOR(TA,12)+.5*UA*UA
      F1D=F2D*HOR(TD,1)+(1.-F2D)*RATIO2*HOR(TD,4)+(1.-F2D)*(1.-RATIO2)*
     1    HOR(TD,12)+.5*UD*UD
      READ (5,2) NIN,NUI,NUE,NVI,NVE
      READ (5,4) (YIN(I),I=1,NYS)
      READ (5,4) (UIN(I),I=1,NIN)
      READ (5,4) (VTIN(I),I=1,NIN)
      READ (5,4) (TIN(I),I=1,NIN)
      READ (5,4) (MFUIN(I),I=1,NIN)
      READ (5,4) (MCO2IN(I),I=1,NIN)
      READ (5,4) (MCOIN(I),I=1,NIN)
      READ (5,4) (MOXIN(I),I=1,NIN)
      READ (5,4) (MH2OIN(I),I=1,NIN)
```

```
      READ (5,4) (MWZIN(I),I=1,NIN)
      IF (KREAD.EQ.0) GO TO 19
      READ (5,4) (TKIN(I),I=1,NIN)
      READ (5,4) (TLIN(I),I=1,NIN)
   19 CONTINUE
C
C ----------- READ INJECTION VALUES
      IF (NUI.LE.0) GO TO 30
      READ (5,4) (XUINJ(I),I=1,NUI)
      READ (5,4) (XLUINJ(I),I=1,NUI)
      READ (5,4) (UINJ(I),I=1,NUI)
      READ (5,4) (VTUINJ(I),I=1,NUI)
      READ (5,4) (TUINJ(I),I=1,NUI)
      READ (5,4) (AUINJ(I),I=1,NUI)
      READ (5,4) (MUINJ(I),I=1,NUI)
      READ (5,4) (ARUINJ(I),I=1,NUI)
      DO 31 I=1,NUI
      DEN=POGSCH/TUINJ(I)
   31 RUINJ(I)=DEN*UINJ(I)
   30 NI=NUI+1
      XUINJ(NI)=2.*ABS(XULAST)
      XLUINJ(NI)=2.*ABS(XULAST)
      NI=NI+1
      IF (NUE.LE.0) GO TO 32
      NE=NI+NUE-1
      READ (5,4) (XUINJ(I),I=NI,NE)
      READ (5,4) (XLUINJ(I),I=NI,NE)
      READ (5,4) (UINJ(I),I=NI,NE)
      READ (5,4) (VTUINJ(I),I=NI,NE)
      READ (5,4) (TUINJ(I),I=NI,NE)
      READ (5,4) (AUINJ(I),I=NI,NE)
      READ (5,4) (MUINJ(I),I=NI,NE)
      READ (5,4) (ARUINJ(I),I=NI,NE)
      DO 33 I=NI,NE
      DEN=POGSCH/TUINJ(I)
   33 RUINJ(I)=DEN*UINJ(I)
   32 NE=NI+NUE
      XUINJ(NE)=2.*ABS(XULAST)
      XLUINJ(NE)=2.*ABS(XULAST)
      NUE=NUI+2
      NUI=1
      IF (NVI.LE.0) GO TO 35
      READ (5,4) (XVINJ(I),I=1,NVI)
      READ (5,4) (UVINJ(I),I=1,NVI)
      READ (5,4) (VINJ(I),I=1,NVI)
      READ (5,4) (VTVINJ(I),I=1,NVI)
      READ (5,4) (TVINJ(I),I=1,NVI)
      READ (5,4) (AVINJ(I),I=1,NVI)
   35 NI=NVI+1
      XVINJ(NI)=2.*ABS(XULAST)
      NI=NI+1
      IF (NVE.LE.0) GO TO 36
      NE=NI+NVE-1
      READ (5,4) (XVINJ(I),I=NI,NE)
      READ (5,4) (UVINJ(I),I=NI,NE)
      READ (5,4) (VINJ(I),I=NI,NE)
      READ (5,4) (VTVINJ(I),I=NI,NE)
      READ (5,4) (TVINJ(I),I=NI,NE)
      READ (5,4) (AVINJ(I),I=NI,NE)
   36 NE=NI+NVE
      XVINJ(NE)=2.*ABS(XULAST)
      NVE=NVI+2
      NVI=1
C
C
      DY=RE-RI
      Y(1)=0.0
      Y(NP3)=1.0
      DO 55 I=1,NP3
   55 Y(I)=Y(I)*DY
C
      DO 400 I=1,NP3
      U(I)=TAB(Y(I),YIN,UIN,NIN)
      F(JFU,I)=TAB(Y(I),YIN,MFUIN,NIN)
      F(JCO2,I)=TAB(Y(I),YIN,MCO2IN,NIN)
      F(JCO,I)=TAB(Y(I),YIN,MCOIN,NIN)
      F(JOX,I)=TAB(Y(I),YIN,MOXIN,NIN)
```

```
      F(JH2O,I)=TAB(Y(I),YIN,XH2OIN,NIN)
      F(JH2,I)=TAB(Y(I),YIN,XH2IN,NIN)
      F(JVT,I)=TAB(Y(I),YIN,VTIN,NIN)
      FS(JT,I)=TAB(Y(I),YIN,TIN,NIN)
      IF (KREAD.EQ.0) GO TO 400
      F(JK,I)=TAB(Y(I),YIN,TKIN,NIN)
      F(JD,I)=CD*F(JK,I)**1.5/(TAB(Y(I),YIN,TLIN,NIN)+1.E-20)
  400 CONTINUE
C
      DO 410 I=1,NP3
      DPDX(I)=0.0
      R(I)=RI+Y(I)*CSALFA
      F(JD,I)=0.
      F(JOH,I)=0.
      F(JHS,I)=0.
      F(JHO,I)=0.
      F(JN,I)=0.
      FS(JN2,I)=1.0
      DO 412 JJ=1,NSPR
      J=JLOC(JJ)
  412 FS(JN2,I)=FS(JN2,I)-F(J,I)
      HPI=0.
      DO 411 JJ=1,NSPR
      J=JLOC(JJ)
  411 HPI=HPI+F(J,I)*HBR(FS(JT,I),JJ)
      F(JH,I)=HPI+FS(JN2,I)*HBR(FS(JT,I),12)+.5*U(I)*U(I)
      IF (KREAD.EQ.1) GO TO 410
      F(JK,I)=AKFAC*U(I)*U(I)
      ALM=ALFAC*(Y(NP3)-Y(I))
      IF (IOUT.NE.0) ALM=AMIN1(ALM,ALFAC*Y(I))
      ALM=AMAX1(ALM,ALFAC*Y(NP3)/100.)
      F(JD,I)=CD*F(JK,I)**1.5/ALM
  410 CONTINUE
      ALM=ALFAC*Y(NP3)
C
      DO 52 I=1,NP3
      P(I)=PRESS
      PSURL(I)=0.
      RII=R(I)
      IF (I.EQ.2) RII=.75*R(2)+.25*R(3)
      IF (I.EQ.NP2) RII=.75*R(NP2)+.25*R(NP1)
      F(JVT,I)=RII*F(JVT,I)
      WMIX=0.
      DO 413 JJ=1,NSPR
      J=JLOC(JJ)
  413 WMIX=WMIX+F(J,I)/W(JJ)
      WMIX=WMIX+FS(JN2,I)/W(12)
      RHO(I)=PRESS/FS(JT,I)/GASCON/WMIX
      IF (I.EQ.1) GO TO 52
      AFLO=.5*(R(I)**2-R(I-1)**2)
      IF (KRAD.EQ.0) AFLO=Y(I)-Y(I-1)
      GM(I)=.5*(RHO(I)*U(I)+RHO(I-1)*U(I-1))*AFLO
   52 CONTINUE
      DO 53 I=2,NP3
   53 GM(I)=GM(I-1)+GM(I)
      FLOTOT=GM(NP3)
      DO 51 I=1,NP3
   51 GM(I)=GM(I)/FLOTOT
C   -
      WMIX=F2A/WFU+(1.-F2A)*.03460
      RDA=PRESS/TA/GASCON/WMIX
      FLOA=RDA*UA*.5*(RB**2-RA**2)
      PSII=FLOA
      PEI=FLOTOT
      PSIE=PSII+PEI
      DYDL9=0.0
C
C     ---------------------------------------------------------------------
CHAPTER66666666666666666666666666666666666  THERMODYNAMIC PROPERTIES  666666
C   ********************300   START OF MAIN LOOP   *********************
   60 CONTINUE
C
C     -------------------------------------------------- TEST 1
      IF(ITEST) 602,601,602
  602 LAB(1)=6HTEST 1
      LAB(2)=6H
      WRITE(6,100) LAB,R(1),PRESS,DX,PSII,PSIE,PEI,FRA,ULIN,PEILIN,AFAC,
```

```
      1        AEXBLM
      LAB(1)=1HU
      LAB(2)=6H
      WRITE(6,100) LAB,(U(I),I=1,NP3)
      LAB(1)=6HF(1,I)
      LAB(2)=6H
      WRITE(6,100) LAB,(F(1,I),I=1,NP3)
      LAB(1)=6HF(2,I)
      LAB(2)=6H
      WRITE(6,100) LAB,(F(2,I),I=1,NP3)
      LAB(1)=6HF(3,I)
      LAB(2)=6H
      WRITE(6,100) LAB,(F(3,I),I=1,NP3)
      LAB(1)=6HF(4,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(4,I),I=1,NP3)
      LAB(1)=6HF(5,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(5,I),I=1,NP3)
      LAB(1)=6HF(6,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(6,I),I=1,NP3)
      LAB(1)=6HF(7,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(7,I),I=1,NP3)
      LAB(1)=6HF(8,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(8,I),I=1,NP3)
      LAB(1)=6HF(9,I)
      LAB(2)=6H
      WRITE (6,100) LAB,(F(9,I),I=1,NP3)
      LAB(1)=6HF(10,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(10,I),I=1,NP3)
      LAB(1)=6HF(11,I
      LAB(2)=6H)
      WRITE (5,100) LAB,(F(11,I),I=1,NP3)
      LAB(1)=6HF(12,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(12,I),I=1,NP3)
      LAB(1)=6HF(13,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(13,I),I=1,NP3)
      LAB(1)=6HF(14,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(14,I),I=1,NP3)
      LAB(1)=6HF(15,I
      LAB(2)=6H)
      WRITE (6,100) LAB,(F(15,I),I=1,NP3)
  601 CONTINUE
C
      DO 200 I=1,NP3
  200 P(I)=P(I)+DPDX(I)*DXOLD
      IF(MASSTR.NE.0) GO TO 64
      DO 65 I=1,NP3
      CPI=RATIO2*CPOR(FS(JT,I),4)+(1.-RATIO2)*CPOR(FS(JT,I),12)
      HPI=RATIO2*HOR(FS(JT,I),4)+(1.-RATIO2)*HOR(FS(JT,I),12)
      FS(JT,I)=AMAX1(1.,FS(JT,I)+(F(JH,I)-.5*U(I)*U(I)-HPI)/CPI)
   65 RHO(I)=P(I)*WMIX/FS(JT,I)/GASCON
      GO TO 66
   64 DO 61 I=1,NP3
      FS(JM2,I)=1.
      DO 607 JJ=1,NSPM
      J=JLOC(JJ)
  607 FS(JM2,I)=FS(JM2,I)-F(J,I)
      HPI=0.
      CPI=0.
      DO 606 JJ=1,NSPM
      J=JLOC(JJ)
      HPI=HPI+F(J,I)*HOR(FS(JT,I),JJ)
  606 CPI=CPI+F(J,I)*CPOR(FS(JT,I),JJ)
      HPI=HPI+FS(JM2,I)*HOR(FS(JT,I),12)
      CPI=CPI+FS(JM2,I)*CPOR(FS(JT,I),12)
      FS(JT,I)=FS(JT,I)+(F(JH,I)-.5*U(I)*U(I)-HPI)/CPI
      FS(JT,I)=AMAX1(FS(JT,I),100.)
      WMIX=0.
      DO 605 JJ=1,NSPM
```

```
      J=JLOC(JJ)
  605 VMIX=VMIX+F(J,I)/W(JJ)
      VMIX=VMIX+FS(NM2,I)/WM2
   61 RHO(I)=P(I)/FS(J3,I)/VMIX/GASCON
   66 CONTINUE
      RHO(2)=RHO(1)
      RHO(NP2)=RHO(NP3)
C     ------------------------------------------------------- TEST 2
      IF(ITEST) 604,603,604
  604 LAB(1)=6HTEST 2
      LAB(2)=6H
      WRITE(6,100) LAB,PRESS,DF,DPDDX,PDGSCN
      LAB(1)=6HFS(1,I
      LAB(2)=1H)
      WRITE(6,100) LAB,(FS(1,I),I=1,NP3)
      LAB(1)=6HFS(2,I
      LAB(2)=1H)
      WRITE(6,100) LAB,(FS(2,I),I=1,NP3)
      LAB(1)=6HRHO(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(RHO(I),I=1,NP3)
  603 CONTINUE
C     ------------------------------ ADJUST R(1)
      IF (KIN.EQ.3) GO TO 609
      R(1)=TAB(XU,XR,ARI,NRP)
      IF (XU.LE.XUINJ(NUI)) GO TO 617
      R(1)=SQRT(R(1)**2+2.*(AUINJ(NUI)-SUM1)/RUINJ(NUI))
  617 IF (IEND.GE.ISTEP.OR.KRAD.EQ.0) GO TO 609
      R(1)=SQRT(RA**2+2.*PSII/RHO(1)/U(1))
C
C     ------------STRIDE1------------STRIDE1------------STRIDE1--------STRIDE1
609   CALL STRIDE(1)
C
C     -------------------------------------------------------------------------
CHAPTER7777777777777777777777777777777777777777777  FORWARD STEP  777777777
      DXOLD=AMAX1(.005*FRA*Y(NP3),DX)
      DX=FRA*Y(NP3)
      IDXFIX=0
      IF(ISTEP.LT.50) DX=.1*DX
      DX=AMIN1(DX,3.*DXOLD)
C
      IF(ISTEP.GE.IEND) GO TO 73
      IF(DX.LT.XEND-XU) GO TO 70
      DX=XEND-XU
      IDXFIX=1
      IEND=ISTEP+1
   70 IF(ISTEP.GE.IOUT) GO TO 71
      IF(DX.LT.XOUT-XU) GO TO 71
      DX=XOUT-XU
      IDXFIX=1
      IOUT=ISTEP+1
   71 IF (DX.LT.XULAST-XU) GO TO 72
      DX=XULAST-XU
      IDXFIX=1
   72 IF( DX.GT.0.) GO TO 73
      IFIN=1
      GO TO 1011
C
   73 XD=XU+DX
C     ------ FURTHER ADJUSTMENTS TO DX ARE MADE IN CHAPTERS 8 AND 9.
C
C     -------------------------------------------------------------------------
CHAPTER8888888888888888888888888  ADJUST LONGITUDINAL CONDITIONS  888888
C
C     CHAPTER8A ------------------------------------BOUNDARY CONDITIONS
C     --------------- I BOUNDARY
      IF(ISTEP-IAX) 9002,50,54
 8000 IF(ISTEP-IENS) 8002,53,54
C     ---------------------------- WALL
 9002 KIN=1
      U(1)=0.
      RMI=0.
      IF(ISTEP.EQ.0) TAUI=0.
      SWALL=0.
      DO 81 JJ=1,NSPM
      J=JLOC(JJ)
      IND1(J)=2
```

PROGRAM MAIN 73/74 OPT=0 TRACE FTN 4.6+439 08/25/78 14.42.35 PAGE 8

```
   81 AJI(J)=0.
      INDI(JM)=2
      AJI(JM)=0.
      DO 74 J=13,1.
      INDI(J)=1
   74 F(J, )=0.0
      IF (I-LUX.EQ.0) GO TO 84
      FS(JT,1)=TWALL
      INDI(JM)=1
      HPI=0.
      DO 76 JJ=1,NSPR
      J=JLOC(JJ)
   76 HPI=HPI+F(J,1)*HOR(TWALL,JJ)
      F(JM,1)=HPI+FS(JM2,1)*HOR(TWALL,12)
      GO TO 84
C     ------------------------- FREE
   83 KIN=2
      TAUI=0.
      U(1)=UA
      RMI=0.
      RU(1)=RHG(1)*U(1)
      F(JM,1)=F1A
      F(JFU,1)=F2A
      DO 181 JJ=2,NSPR
      J=JLOC(JJ)
  181 F(J,1)=0.
      F(JOX,1)=RATIO2*(1.-F2A)
      F(JVT,1)=R(1)*VTA
      F(JK,1)=AKFAC*UA*UA
      F(JD,1)=CD*F(JK,1)**1.5/ALM
      GO TO 84
C     -------------------- SYMMETRY AXIS
   8G KIN=3
      RMI=0.
      R(1)=RA
      PSII=0.
      TAUI=0.
C     -----------------------------AXIAL INJECTION
   84 RI=TAB(XD,XP,API,NBP)
      IF (XD.LE.XUINJ(NUI)) GO TO 382
      IF (ABS(AUINJ(NUI)-SUM1).GT.1.E-10) GO TO 380
      NUI=NUI+1
      SUM1=0.
      GO TO 382
  380 KIN=2
      TAUI=0.
      ARG=2.*ABS(SUM1/AUINJ(NUI)-.5)
      U(1)=UINJ(NUI)*(1.-ARG**SLN)/UBAT
      T=TUINJ(NUI)
      F(JM,1)=RATIO2*HOR(T,4)+(1.-RATIO2)*HOR(T,12)
      DO 387 JJ=1,NSPR
      J=JLOC(JJ)
  387 F(J,1)=0.
      F(JOX,1)=RATIO2
      F(JVT,1)=R(1)*VTUINJ(NUI)
      VEC2=UINJ(NUI)**2+VTUINJ(NUI)**2
      F(JK,1)=AKFAC*VEC2
      F(JD,1)=CD*F(JK,1)**1.5/ALM
      FS(JT,1)=TUINJ(NUI)
      RHO(1)=POGSCH/FS(JT,1)
      RU(1)=RHO(1)*U(1)
      RI=SQRT(RI**2+2.*(AUINJ(NUI)-SUM1)/RUINJ(NUI))
  382 CONTINUE
C     -----------------------------------RADIAL INJECTION
      IF (XD.LE.XVINJ(NVI)) GO TO 394
      IF (ABS(AVINJ(NVI)-SUM3).GT.1.E-10) GO TO 390
      NVI=NVI+1
      SUM3=0.
      GO TO 394
  390 IF (KIN.NE.2) GO TO 392
      PSII=PSII-(AUINJ(NVI)-SUM1)
      SUM1=AUINJ(NUI)
      KIN=1
      RI=TAB(XD,XP,API,NBP)
  392 U(1)=UVINJ(NVI)
      T=TVINJ(NVI)
      F(JM,1)=RATIO2*HOR(T,4)+(1.-RATIO2)*HOR(T,12)
```

```
      DO 388 JJ=1,NSPM
      J=JLOC(JJ)
  388 F(J,1)=0.
      F(JOX,1)=RATIO2
      F(JVT,1)=R(1)*VTVINJ(NVI)
      VEC2=UVINJ(NVI)**2+VINJ(NVI)**2+UTVINJ(NVI)**2
      F(JK,1)=AKFAC*VEC2
      F(JD,1)=CD*F(JK,1)**1.5/ALM
      DO 207 J=1,NF
      INDE(J)=1
  207 FS(JT,1)=TVINJ(NVI)
      RHO(1)=PDGSCM/FS(JT,1)
      RMI=R(1)*RHO(1)*VINJ(NVI)
      IF (ABS(RMI)*DX.LT.AVINJ(NVI)-SUM3) GO TO 394
      RMI=(AVINJ(NVI)-SUM4)/DX
  394 CONTINUE
C     ---------------------- E BOUNDARY
      IF (ISTEP-IOUT) 8004,85,85
C     ---------------------- WALL
 8004 KEX=1
      U(NP3)=0.
      RME=0.
      IF(ISTEP.EQ.0) TAUE=0.
      EWALL=9.
      DO 82 JJ=1,NSPM
      J=JLOC(JJ)
      INDE(J)=2
   82 AJE(J)=0.
      INDE(JH)=2
      AJE(JH)=0.
      DO 75 J=13,15
      INDE(J)=1
   75 F(J,NP3)=0.0
      IF (IFLUX.EQ.0) GO TO 86
      INDE(JH)=1
      FS(JT,NP3)=TWALL
      HPI=0.
      DO 77 JJ=1,NSPM
      J=JLOC(JJ)
   77 HPI=HPI+F(J,NP3)*HDR(TWALL,JJ)
      F(JH,NP3)=HPI+FS(JN2,NP3)*HDR(TWALL,12)
      GO TO 86
C     ----------------------------------------FREE
   85 KEX=2
      TAUE=0.
      U(NP3)=UD
      RU(NP3)=RHO(NP3)*U(NP3)
      DO 158 JJ=1,NSPM
      J=JLOC(JJ)
  158 F(J,NP3)=0.
      F(JOX,NP3)=RATIO2*(1.-F2D)
      F(JH,NP3)=F1D
      F(JFU,NP3)=F2D
      F(JVT,NP3)=R(NP3)*VTD
      F(JK,NP3)=AKFAC*UD*UD
      F(JD,NP3)=CD*F(JK,NP3)**1.5/ALM
C     -------------------------AXIAL INJECTION
   86 RE=TAB(XD,XR,ARE,NBP)
      IF (XD.LE.XUINJ(NUE)) GO TO 372
      IF (ABS(AUINJ(NUE)-SUM2).GT.1.E-10) GO TO 369
      NUE=NUE+1
      SUM2=0.
      GO TO 372
  369 KEX=2
      TAUE=0.
      ARG=2.*ABS(SUM2/AUINJ(NUE)-.5)
      U(NP3)=UINJ(NUE)*(1.-ARG**SLN)/URAT
      T=TUINJ(NUE)
      F(JH,NP3)=RATIO2*HDR(T,4)+(1.-RATIO2)*HDR(T,12)
      DO 371 JJ=1,NSPM
      J=JLOC(JJ)
  371 F(J,NP3)=0.
      F(JOX,NP3)=RATIO2
      F(JVT,NP3)=R(NP3)*VTUINJ(NUE)
      VEC2=UINJ(NUE)**2+VTUINJ(NUE)**2
      F(JK,NP3)=AKFAC*VEC2
      F(JD,NP3)=CD*F(JK,NP3)**1.5/ALM
```

```
      FS(JT,NP3)=TVINJ(NVE)
      RHO(NP3)=PDGSCN/FS(JT,NP3)
      RU(NP3)=U(NP3)*RHO(NP3)
      RE=SQRT(RE**2-2.*(AUINJ(NUE)-SUM2)/RUINJ(NUE))
  272 CONTINUE
C     ----------------------------------RADIAL INJECTION
      IF (XB.LE.XVINJ(NVE)) GO TO 202
      IF (ABS(AVINJ(NVE)-SUM4).GT.1.E-10) GO TO 206
      SUM4=0.
      NVE=NVE+1
      GO TO 202
206   IF (KEX.NE.2) GO TO 209
      PSIE=PSIE+(AUINJ(NUE)-SUM2)
      SUM2=AUINJ(NUE)
      KEX=1
      RE=TAB(XD,XR,ARE,NBP)
  209 U(NP3)=UVINJ(NVE)
      T=TVINJ(NVE)
      F(JM,NP3)=RATIO2*WDR(T,6)+(1.-RATIO2)*WDR(T,12)
      DO 399 JJ=1,NSPM
      J=JLCC(JJ)
  399 F(J,NP3)=0.
      F(JOX,NP3)=RATIO2
      F(JVT,NP3)=R(NP3)*VTVINJ(NVE)
      VEC2=UVINJ(NVE)**2+VINJ(NVE)**2+VTVINJ(NVE)**2
      F(JK,NP3)=AKFAC*VEC2
      F(JD,NP3)=CD*F(JK,NP3)**1.5/ALM
      DO 208 J=1,NF
208   INBE(J)=1
      FS(JT,NP3)=TVINJ(NVE)
      RHO(NP3)=PDGSCN/FS(JT,NP3)
      RME=R(NP3)*RHO(NP3)*VINJ(NVE)
      IF (ABS(RME)*DX.LT.AVINJ(NVE)-SUM4) GO TO 202
      RME=-(AVINJ(NVE)-SUM4)/DX
  202 CONTINUE
C
C     CHAPTER 8B ----------------------------------- DUCT GEOMETRY
      IF (ISTEP.GE.IOUT) GO TO 64
      IF(ISTEP.GT.0) GO TO 87
      ROUT=RO
      ADUD=(R(NP3)**2-R(1)**2)*.5
      IF (KRAD.EQ.0) ADUD=Y(NP3)-Y(1)
   87 ADUU=ADUD
      AIN=.5*R(1)**2
      IF (ISTEP.EQ.IOUT) ADUU=.5*ROUT**2
      AFLU=R(NP3)**2*.5-AIN
      IF (KRAD.EQ.0) AFLU=Y(NP3)-Y(1)
      AEX=AFLU-ADUU
      AEXD=AEX/AFLU
      IF (IDXFIX.EQ.1) GO TO 68
      IF(ABS(AEXD).GT.AEXDLM) DX=DX*AEXDLM/ABS(AEXD)
      XD=XU+DX
64    ADUD=.5*(RE**2-RI**2)
      IF (KRAD.EQ.0) ADUD=RE-RI
      DA=AFAC*(ADUD-AFLU)
C
C     CHAPTER 8C ------------------------- SUBSONIC PRESSURE GRADIENT
C     --------------------------UBAR
   89 UBAR=0.
      DO 920 I=2,NP1
  920 UBAR=UBAR+(U(I)+U(I+1))*OMD(I)
      UBAR=.5*UBAR
      IF(KIN.EQ.2) UBAR=(UBAR-UA)*PEI/PSIE+UA
C     --------------------------------SUBSONIC FLOW
  803 IF (ISTEP-IOUT) 822,823,823
  823 DPDX=0.
      GO TO 824
C     -------------------------------- CONFINED SUBSONIC FLOW
  822 GO TO (830,835), IDPDX
  835 IF (ISTEP.EQ.0.OR.KIN.EQ.2) GO TO 830
C     -------------   GRID FILLING DUCT  VERSION   ----------
      RDUBAR=PEI/ADUU
      ROBAR=RDUBAR/UBAR
      DUDP=-1./(RDUBAR+(TAUE*R(NP3)-TAUI*R(1))*DX/ADUU/UBAR)
      UDRODP=RDUBAR/GAMMA/P(NP3)
      DPDU=RDUBAR*(AFLU/ADUU-1.)
      DPC=DPDU/(ROBAR*DUDP+UDRODP)
```

```
      UFAC=DPC*DUDP/UBAR+1.
C     --------  ADJUST VELOCITY PRESSURE AND DENSITY PROFILES  --------
      DO 840 I=1,NP3
      U(I)=U(I)*UFAC
      P(I)=P(I)+DPC
  840 RHO(I)=RHO(I)*(1.+GAMMA*DPC/P(I))
      DP=DP+DPC
      DPDDX=DP/DXOLD
C     --------  RECALCULATE DISTANCES  ----------
      CALL STRIDE(I)
      GO TO 824
C     -------------  STANDARD GENMIX VERSION  ---------
  830 FLOTOT=PSIE-PSII*FLOAT(I/KIN)
      DYNMED=UBAR*FLOTOT/AFLU
      DPDDX=(DYNMED*DA/DX-TAUI*R(I)-TAUE*R(NP3)*2.*UBAR*(RME-RMI))/ADUD
      DP=DPDDX*DX
  824 CONTINUE
C     ----------  2*FLOW AREAS  -------------
      DO 307 I=2,NP2
  307 RDY(I)=PEI*(OM(I+1)-OM(I-1))/RHO(I)/U(I)
      GO TO (310,312,312), KIN
  310 RDY(2)=(R(1)+.5*(R(2)+R(3)))*YI
      GO TO 313
  312 RDY(2)=PEI*OM(3)/RHO(3)/U(3)
  313 GO TO (314,315,315), KEX
  314 RDY(NP2)=(R(NP3)+.5*(R(NP2)+R(NP1)))*YE
      GO TO 316
  315 RDY(NP2)=PE*(1.-OM(NP1))/RHO(NP1)/U(NP1)
  316 CONTINUE
      RDY(1)=0.0
      RDY(NP3)=0.0
      IF (ISWRL.EQ.0) GO TO 227
C     --------  PRESSURE GRADIENT W/SWIRL EFFECTS INCLUDED  ----------
      VOR2=(F(JVT,NP2)/(.75*R(NP2)+.25*R(NP1))**2)**2
      PALFA=0.5*PEI*CSALFA
      PD=0.
      DPDX(NP2)=0.0
      DO 225 JI=3,NP2
      I=NP3-JI+1
      VOR2P1=VOR2
      RII=R(I)
      IF (I.EQ.2) RII=.75*R(2)+.25*R(3)
      VOR2=(F(JVT,I)/RII**2)**2
      PD=PD-PALFA*(VOR2/U(I)+VOR2P1/U(I+1))*OMD(I)
      IF (ISTEP.GT.0) GO TO 224
      PSWRL(I)=PD
      P(I)=P(I)+PD
      IF (I.EQ.2) P(1)=P(2)
  224 DPDX(I)=(PD-PSWRL(I))/DXOLD
  225 PSWRL(I)=PD
      IF (KEX.EQ.2) GO TO 260
      DPDXDA=0.0
      SRDY=0.0
      DO 250 I=2,NP2
      SRDY=SRDY+RDY(I)
  250 DPDXDA=DPDXDA+DPDX(I)*DXOLD*RDY(I)
      DP=DP-DPDXDA/SRDY
      DO 255 I=2,NP2
  255 DPDX(I)=DPDX(I)+DP/DXOLD
  260 CONTINUE
      DPDX(1)=DPDX(2)
      DPDX(NP3)=DPDX(NP2)
      GO TO 242
C     --------  PRESSURE GRADIENT FOR NON-SWRLING FLOW  ----------
  227 DO 825 I=1,NP3
  825 DPDX(I)=DPDDX
C     ----------------------------------------------------- TEST 3
  242 IF (ITEST) 802,801,802
  802 LAB(1)=6HTEST 3
      LAB(2)=6H
      WRITE(6,100) LAB,UBAR,DYNMED,DX,DA,DPDDX,AEXD,RMI
      WRITE(6,101) LAB,ISTEP,KIN,KEX,IAX,IEND,IOUT
      LAB(1)=4HY(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(Y(I),I=1,NP3)
      LAB(1)=4HR(I)
      LAB(2)=6H
```

```
      WRITE(6,100) LAB,(R(I),I=1,NP3)
      LAB(1)=5HRU(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(RJ(I),I=1,NP3)
      LAB(1)=6HDPDX(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(DPDX(I),I=1,NP3)
      LAB(1)=6HPSWRL(
      LAB(2)=6HI)
      WRITE (6,100) LAB,(PSWRL(I),I=1,NP3)
  801 CONTINUE
C
C ------------------------------------------------------------------------
CHAPTER999999999999999999999  TRANSPORT AND ENTRAINMENT PROPERTIES   9999
C ----   LAMINAR VISCOSITY ASSUMED TO BE THAT OF AIR  ----------------
 900  CONTINUE
      DO 98 I=1,NP3
      EMU(I)=VISCO(FS(JT,I))
   98 CONTINUE
      EMU(2)=EMU(1)
      EMU(NP2)=EMU(NP3)
C     ------------------------------------------------------- TEST 4
      IF(ITEST) 902,901,902
  902 LAB(1)=6HTEST 4
      LAB(2)=6H
      WRITE(6,100) LAB,RMI,RME,PEI
      LAB(1)=6HEMU(I)
      LAB(2)=6H
      WRITE(6,100) LAB,(EMU(I),I=1,NP3)
  901 CONTINUE
C
C     -----------AUX-----------AUX-----------AUX-----------AUX-----------AUX
      CALL AUXO(0)
C     ----------------------------------- ENTRAINMENT CONTROL.
      IF(KIN.NE.2) GO TO 94
      RAT=ABS((U(3)-U(1))/(U(NP3)-U(1)+1.E-30))
      IF(RAT.LT.ULIM) EM U(2)=EM U(2)*RAT/ULIM
      RMI=2.*EM U(2)
   94 CONTINUE
      IF(KEX.NE.2) GO TO 97
      RAT=ABS((U(NP1)-U(NP3))/(U(NP3)-U(1)+1.E-30))
      RME=-2.*EM U(NP1)
      IF(RAT.LT.ULIM) RME=RME*(RAT/ULIM)**2
 97   IF (IDXFIX.EQ.1) GO TO 96
C     ------------ LIMIT ON INCREMENT IN PEI.
      IF((ABS(RMI)+ABS(RME))*DX.LT.PEI*PEILIM) GO TO 96
      DX=PEI*PEILIM/(ABS(RMI)+ABS(RME))
      XD=XU+DX
   96 CONTINUE
      IF (XD.LE.XUINJ(NUI)) GO TO 91
      IF (ABS(RMI)*DX.LT.AUINJ(NUI)-SUM1) GO TO 91
      RMI=(AUINJ(NUI)-SUM1)/DX
   91 IF (XD.LE.XUINJ(NUE)) GO TO 92
      IF (ABS(RME)*DX.LT.AUINJ(NUE)-SUM2) GO TO 92
      RME=-(AUINJ(NUE)-SUM2)/DX
   92 CONTINUE
C     ------------ ADJUSTMENT OF DX TO REACH AXIS.
      IF (IEND.GT.ISTEP) GO TO 95
      IF(ISTEP.GE.IAX) GO TO 95
      IF(PSII.GT.RMI*DX.OR.IAX.EQ.ISTEP+1) GO TO 95
      RMI=PSII/DX
      IAX=ISTEP+1
C
C     -----------STRIDE2-----------STRIDE2-----------STRIDE2---------STRIDE2
   95 CALL STRIDE(2)
C
C ------------------------------------------------------------------------
C     -----------AUXS-----------AUXS-----------AUXS-----------AUXS-------
      CALL AUXS
C ------------------------------------------------------------------------
CHAPTER 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10   OUTPUT    10 10 10
 1000 IF(ISTEP.GT.0) GO TO 106
      WRITE (6,9000)
 9000 FORMAT (1H1)
CHAPTER 10A  ---------------------------------------   HEADINGS
C
      WRITE (6,1013) TITLE,MODER,IDPSX,MODEL,MASSTR,INERT,KRAD,IFLUX
```

```
      1013 FORMAT (1H1,12A6/12A6/7H MODER=,I3,7H IDPBX=,I3,7H MODEL=,I3,
          1 8H MASSTR=,I3,7H INERT=,I3,6H KRAD=,I3,7H IFLUX=,I3)
      C
           WRITE (6,1010) UA,UD,TA,TD,RA,RB,RD,XEND,XOUT,XULAST,PRESS,
          1 PREXP1,ARCON1,CR1,VTA,VTD
      1010 FORMAT (1H ,1X,2HUA,8X,2HUD,8X,2HTA,8X,2HTD,8X,2HRA,8X,2HRB,8X,
          1 2HRD,8X,4HXEND,6X,4HXOUT,6X,6HXULAST/1H ,1P10E10.3/1H ,
          2 6H PRESS,5X,6HPREXP1,4X,6HARCON1,4X,3HCR1,7X,3HVTA,7X,3HVTD/1X,
          2 1P10E10.3)
      C
           LAB(1)=5HOMEGA
           LAB(2)=6H
           WRITE(6,100) LAB,(OM(I),I=1,NP3)
           PRESS1=PRESS
           NINJ=12
           IF (XUINJ(NUI).GT.XULAST.AND.XUINJ(NUE).GT.XULAST) GO TO 1200
           WRITE (6,1205)
      1205 FORMAT (/6X,'AXIAL INJECTION'/6X,15(1H*)//6X,'SLOT',4X,
          1 'BOUNDARY',9X,'X',9X,'XL',10X,'U',9X,'VT',7X,'TEMP',7X,'MDOT',
          2 10X,'M',9X,'AR'/10(3X,8(1H*)))
           INDX=0
           IPT=0
           DO 1210 II=1,NINJ
           IF (INDX.EQ.2) GO TO 1210
           IF (XUINJ(II).GT.XULAST) INDX=INDX+1
           IF (XUINJ(II).GT.XULAST) GO TO 1210
           IB=1HI
           IF (II.GE.NUE) IB=1HE
           IPT=IPT+1
           WRITE (6,1215) IPT,IB,XUINJ(II),XLUINJ(II),UINJ(II),VTUINJ(II),
          1 TUINJ(II),AUINJ(II),HUINJ(II),ARUINJ(II)
      1215 FORMAT (7X,I2,9X,A1,3X,8(1PE11.3))
      1210 CONTINUE
      1200 IF (XVINJ(NVI).GT.XULAST.AND.XVINJ(NVE).GT.XULAST) GO TO 1220
           WRITE (6,1225)
      1225 FORMAT (//6X,'RADIAL INJECTION'/6X,16(1H*)//6X,'SLOT',4X,
          1 'BOUNDARY',9X,'X',10X,'U',9X,'V',9X,'VT',7X,'TEMP',7X,'MDOT'/
          2 8(3X,8(1H*)))
           INDX=0
           IPT=0
           DO 1230 II=1,NINJ
           IF (INDX.EQ.2) GO TO 1230
           IF (XVINJ(II).GT.XULAST) INDX=INDX+1
           IF (XVINJ(II).GT.XULAST) GO TO 1230
           IB=1HI
           IF (II.GE.NVE) IB=1HE
           IPT=IPT+1
           WRITE (6,1215) IPT,IB,XVINJ(II),UVINJ(II),VINJ(II),VTVINJ(II),
          1 TVINJ(II),AVINJ(II)
      1230 CONTINUE
      1220 CONTINUE
       106 CONTINUE
      C    -------------------------------------------------- TEST 5
           IF(ITEST) 1002,1001,1002
      1002 LAB(1)=6HTEST 5
           LAB(2)=6H
           WRITE(6,100) LAB,RMI,RME,DX
      1001 CONTINUE
      C
      CHAPTER 10B  -------------------------------------- TESTS FOR PRINTOUT
      C  -  ------ IPRINT=0 GIVES NO OUTPUT,  =1 GIVES SINGLE VARIABLES ONLY,
      C                 =2 GIVES BOTH SINGLE AND ARRAY (PROFILE) VARIABLES.
      1011 IPRINT=0
           IF (MOD(ISTEP,NSTAT).EQ.0) IPRINT=1
           IF (MOD(ISTEP,NPROF).EQ.0) IPRINT=2
           IF(ISTEP.EQ.IEND.OR.ISTEP.EQ.IAX.OR.ISTEP.EQ.IOUT) IPRINT=2
           IF(ITEST.NE.0.OR.IFIN.NE.0) IPRINT=2
           IF (MOD(ISTEP,NPLOT).EQ.0.AND.ISTEP.GT.0) IPRINT=3
      C    ------ THE NEXT STATEMENT PROVIDES A PLOT JUST PRIOR TO TERMINATION
           IF(XU.GE.XULAST.OR.IFIN.NE.0.OR.ISTEP.EQ.LASTEP) IPRINT=3
      C
      CHAPTER 10C  ---------------------------SINGLE STATION VARIABLES.
           IF(IPRINT.EQ.0) GO TO 110
           PRESSD=P(NP3)/PRESS1-1.
           WRITE (6,1030) ISTEP,IAX,IEND,IOUT,KIN,KEX,DX,PSII,PSIE,RMI,RME,
          1 PEI,PRESSD,AFXD
      1030 FORMAT(7H0ISTEP=,I5,5H IAX=,I5,6H IEND=,I5,6H IOUT=,I5,5H KIN=,I2,
```

```
     1 5H KEX=,I2,4H DX=,1PE11.3,6H PSII=,E11.3,6H PSIE=,E11.3/
     2 5H RMI=,E11.3,5H RME=,E11.3,5H PEI=,E11.3,8H PRESSD=,E11.3,
     3 6H AEXD=,E11.3)
C
C
      UBAR=0.
      DO 1020 J=1,NF
      AJID(J)=0.0
      AJED(J)=0.0
 1020 FLUX(J)=0.
      PFLUX=0.0
      DO 1021 I=2,NP1
      UBAR=UBAR+DMD(I)*(U(I)+U(I+1))
      PFLUX=PFLUX+PSWRL(I)*RDV(I)
      DO 1021 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1021
      FLUX(J)=FLUX(J)+DMD(I)*(F(J,I)+F(J,I+1))
 1021 CONTINUE
      UBAR=.5*UBAR
      UFLUX=PEI*UBAR+PFLUX
      DO 1022 J=1,NF
 1022 FLUX(J)=.5*PEI*FLUX(J)
C
      UREF=UBAR
      RUREF=PEI/.5/(R(1)+R(NP3))/Y(NP3)
      DO 1023 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1023
      DFI(J)=FLUX(J)/PEI-F(J,1)
      DFE(J)=DFI(J)+F(J,1)-F(J,NP3)
 1023 CONTINUE
      UFLUX=UFLUX-PSIE*U(NP3)+U(1)*PSII
      FLUX(JFU)=FLUX(JFU)-PSIE*F2D+F2A*PSII
      FLUX(JH)=FLUX(JH)-PSIE*F1D+F1A*PSII
C
      WRITE (6,1031) XU,UFLUX,(FLUX(J),J=1,NF)
 1031 FORMAT (4H XU=,1PE11.3,7H UFLUX=,E11.3,9H FLUX(J)=,7E11.3/42X,
     1  8E11.3)
C
      IF(KIN.NE.1) GO TO 1024
      TAUID=TAUI/UREF/RUREF
      DO 1025 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1025
      AJID(J)=AJI(J)/RUREF/DFI(J)
 1025 CONTINUE
      WRITE(6,1029) KIN,TAUID,(AJID(J),J=1,NF)
 1029 FORMAT (5H KIN=,I2,7H TAUID=,1PE11.3,9H AJID(J)=,7E11.3/34X,
     1  8E11.3)
C
 1024 IF(KEX.NE.1) GO TO 1026
      TAUED=TAUE/UREF/RUREF
      DO 1027 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 1027
      AJED(J)=AJE(J)/RUREF/DFE(J)
 1027 CONTINUE
      WRITE(6,1028) KEX,TAUED,(AJED(J),J=1,NF)
 1028 FORMAT (5H KEX=,I2,7H TAUED=,1PE11.3,9H AJED(J)=,7E11.3/34X,
     1  8E11.3)
 1026 CONTINUE
C
CHAPTER 100   ---------------------------------PROFILES AND OTHER ARRAYS.
      IF(IPRINT.EQ.1) GO TO 110
C
      LAB(1)=6HR1,Y'S
      LAB(2)=6H
      DIV=1.
      DO 1095 I=1,NP3
 1095 OUT(I)=Y(I)/DIV
      WRITE (6,190) LAB,R(1),(OUT(I),I=2,NP2,ITHI4),Y(NP3)
      XAXIS=4HY(I)
      DO 1085 I=1,NP3
 1085 XPLOT(I)=OUT(I)
C
      LAB(1)=1HU
      LAB(2)=6H
      SUB=0.
      DIV=1.
      IF(KIN.EQ.3) DIV=U(1)+1.E-30
```

```
      DO 1094 I=1,NP3
 1094 OUT(I)=(U(I)-SUB)/DIV
      IF (MOVEL.NE.1) WRITE (6,100) LAB,U(1),(OUT(I),I=2,NP2,ITHIN),
     1 U(NP3)
      NY=1
      YAXES(1,1)=6HVELOCI
      YAXES(1,2)=2HTY
      SYMBOL(1)=1HU
      DO 1084 I=1,NP3
 1084 YPLOT(1,I)=OUT(I)
C
      INDX=0
      DO 1080 KV=1,NF
      KVV=KV+INDX
      IF (IPRNT(KVV).EQ.0) GO TO 1080
      LAB(1)=LAB1(KVV)
      LAB(2)=LAB2(KVV)
      DO 1082 I=1,NP3
 1082 OUT(I)=F(KV,I)
      IF (KV.NE.JVT) GO TO 1075
      VTMAX=0.
      DO 1086 I=2,NP3
      DIV=R(I)
      IF (I.EQ.2) DIV=.75*R(2)+.25*R(3)
      IF (I.EQ.NP2) DIV=.75*R(NP2)+.25*R(NP1)
      OUT(I)=OUT(I)/DIV
 1086 VTMAX=AMAX1(VTMAX,OUT(I))
 1075 IF (KV.NE.JD) GO TO 1076
      DO 1077 I=1,NP3
 1077 OUT(I)=CD*F(JK,I)**1.5/(OUT(I)+1.E-20)
 1076 WRITE (6,100) LAB,F(KV,1),(OUT(I),I=2,NP2,ITHIN),F(KV,NP3)
      IF (IPLOT(KVV).EQ.0) GO TO 1080
      NY=NY+1
      YAXES(NY,1)=LAB1(KVV)
      YAXES(NY,2)=LAB2(KVV)
      SYMBOL(NY)=SYM(KVV)
      DO 1090 I=1,NP3
 1090 YPLOT(NY,I)=OUT(I)
 1080 CONTINUE
C
      INDX=NF
      DO 1180 KV=1,NFS
      KVV=KV+INDX
      IF (IPRNT(KVV).EQ.0) GO TO 1180
      LAB(1)=LAB1(KVV)
      LAB(2)=LAB2(KVV)
      DO 1182 I=1,NP3
 1182 OUT(I)=FS(KV,I)
      WRITE (6,100) LAB,FS(KV,1),(OUT(I),I=2,NP2,ITHIN),FS(KV,NP3)
      IF (IPLOT(KVV).EQ.0) GO TO 1180
      NY=NY+1
      YAXES(NY,1)=LAB1(KVV)
      YAXES(NY,2)=LAB2(KVV)
      SYMBOL(NY)=SYM(KVV)
      DO 1190 I=1,NP3
 1190 YPLOT(NY,I)=OUT(I)
 1180 CONTINUE
C
      LAB(1)=6HPRESS
      IF (ISURL.EQ.0) GO TO 1100
      LAB(2)=6H
      SUB=P(NP3)
      DIV=1.0
      DO 1112 I=1,NP3
 1112 OUT(I)=(P(I)-SUB)/DIV
      WRITE (6,100) LAB,P(1),(OUT(I),I=2,NP2,ITHIN),P(NP3)
 1100 IF (MODEL.NE.2) GO TO 1104
      LAB(1)=6HAMU(I)
      LAB(2)=6H
      WRITE (6,100) LAB,AMU(1),(AMU(I),I=2,NP2,ITHIN),AMU(NP3)
 1104 CONTINUE
      IF (IPRINT.EQ.2) GO TO 110
      WRITE(6,1070) XU,ISTEP
 1070 FORMAT(1H ,11HPLOT AT XU=,1PE11.3,8H, ISTEP=,I5)
      DO 1071 J=1,NY
      YPLOT(J,2)=YPLOT(J,1)
 1071 YPLOT(J,NP2)=YPLOT(J,NP3)
```

```
PROGRAM MAIN        73/74    OPT=0 TRACE                    FTN 4.6+439        08/24/78  14.42.35        PAGE    16

          CALL PLOTS(XPLOT,43,NP3,XAXIS,YPLOT,10,NY,YAXES,SYMBOL)          MA       1152
      C ----------------------------------------------------------------   MA       1153
      CHAPTER 11  11  11  11  11  11  11  11  11  11  11  END OF MAIN LOOP MA       1154
        110 IF((ISTEP.GE.LASTEP.OR.XU.GE.XULAST.OR.IFIN.NE.0) GO TO 111)   MA       1155
      C                                                                    MA       1156
      C   -----------STRIDE3-----------STRIDE3-----------STRIDE3--------STRIDE3  MA  1157
          CALL STRIDE(3)                                                   MA       1158
          IF(I,IN) 1011,60,111                                             MA       1159
      C                                                                    MA       1160
      C   ------------------------------------------------ TERMINATION     MA       1161
        111 WRITE(6,112) ISTEP,LASTEP,XU,XULAST,IFIN                       MA       1162
        112 FORMAT(23H TERMINATED WITH ISTEP=,I5,8H LASTEP=,I5,            MA       1163
           1 4H XU=,1PE11.3,8H XULAST=,E11.3,6H IFIN=,I3)                  MA       1164
      C ----------------------------------------------------------------   MA       1165
        120 CONTINUE                                                       MA       1166
            STOP                                                           MA       1167
        100 FORMAT (1H0,A6,A2,1P11E11.3/(9X,11E11.3))                      MA       1168
        101 FORMAT (1H0,A6,A2,11I11)                                       MA       1169
            END                                                            MA       1170

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

     162    I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
     791    I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
     795    I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
```

```
FUNCTION TAB        73/74    OPT=0 TRACE                    FTN 4.6+439        08/24/78  14.42.35        PAGE    1

 1                FUNCTION TAB (X,XX,YY,NTAB)                                  TA      2
 2                DIMENSION XX(1),YY(1)                                        TA      3
 3                IF (NTAB.GT.0) GO TO 5                                       TA      4
 4                TAB=0.0                                                      TA      5
 5                RETURN                                                       TA      6
 6              5 F=1.                                                         TA      7
 7                IF (XX(1).GT.XX(2)) F=-F                                     TA      8
 8                DO 10 J=1,NTAB                                               TA      9
 9                I=J                                                          TA     10
10                IF (F*(XX(I)-X)) 10,40,20                                    TA     11
11             10 CONTINUE                                                     TA     12
12             20 IF (I.NE.1) GO TO 30                                         TA     13
13                I=2                                                          TA     14
14             30 J=I-1                                                        TA     15
15                DEL=XX(I)-XX(J)                                              TA     16
16                IF (DEL.EQ.0.0) GO TO 50                                     TA     17
17                TAB=(YY(I)*(X-XX(J))-YY(J)*(X-XX(I)))/DEL                    TA     18
18                RETURN                                                       TA     19
19             40 TAB=YY(I)                                                    TA     20
20                RETURN                                                       TA     21
21             50 WRITE (6,60) X,I,J                                           TA     22
22                CALL EXIT                                                    TA     23
23             60 FORMAT (' *** ERROR IN SUBROUTINE TAB ***',E15.4,2I5)        TA     24
24                END                                                          TA     25

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM
      7     I       XX        ARRAY REFERENCE OUTSIDE DIMENSION BOUNDS.
```

```
FUNCTION VISCO      73/74   OPT=2 TRACE               FTN 4.6+439        08/24/78  15.42.35       PAGE    1

                 FUNCTION VISCO(T)                                            TA      26
                 IF (T.GT.667.) GO TO 10                                      TA      27
                 VISCO=1.800E-5*(T/294.4)**0.76                               TA      28
                 RETURN                                                       TA      29
              10 VISCO=4.464E-5*SQRT(T/1111.)                                 TA      30
                 RETURN                                                       TA      31
                 END                                                          TA      32
```

```
      SUBROUTINE AUX(NV)
      COMMON/COMA/A(43),AJE(15),AJI(15),B(43),C(43),CSALFA,D(43),
     1 DPDX(43),DX,EMU(43),F(15,43),FS(3,43),IAX,IEND,IFIN,INDE(15),
     2 INDI(15),IOUT,ISTEP,ITEST,IUTRAP,JS,JSW,JV,JT,KEX,KIN,KRAD,N,
     3 NO2,NF,NOVEL,NP1,NP2,NP3,OM(43),OMO(43),P(43),PEI,PR(15),
     4 PREF(15),PSIE,PSII,R(43),RHO(43),RU(43),RME,RMI,SD(43),SU(43),
     5 TAUE,TAUI,U(43),XD,XU,Y(43),YE,YI,PSWRL(43),RDY(43),ISOLVE(15),
     6 US(43),AMU(43),SUM1,SUM2,SUM3,SUM4,FOGSCN,FDIFI(15),FDIFE(15),
     7 GE(15),GI(15),JLOC(12),W(12),JM,JFU,JCO2,JCO,JCX,JH2O,JOH,JO,JHS,
     8 JH2,JN,JNO,JN2,JVT,JD,JK,JT,NRY,NSP,NSPM,ABSOR,SCATR,SOM(200),
     9 TERM1,TERM2,ISMAX,EFU,EO2,EH2O,ERO,EPR
      COMMON/COMB/AK,ALMG,EWALL,FR,M,MFU,INERT,MASSTR,MODEL,PRESS,
     1 UBAR,UFAC,C1,C2,CD,C2VT,AKFAC,ALFAC,ARCON1,ARCON2,PREXP1,CO75,
     2 PREXP2,CR1,CR2,MODER,MODCP,RATIO1,RATIO2,RATIO3,RATIO4,RATIO5,
     3 CZ,MY,DXOLD,WFU,WCO2,WCO,WOX,WH2O,WOH,WO,WH,
     4 WH2,WN,WNO,WN2
C/-------- SUBROUTINE FOR PROGRAM GENMIX 4A
      DIMENSION LAB(2),DUDY(43),GENP(43),EMUT(43),EMUL(43)
      DIMENSION TSOR(14)
C
      ENTRY AUXO
C     -------- CALCULATE TURB VISCOSITY FROM TWO EQUATION MODEL --------
      IF (MODEL.EQ.1) GO TO 200
      DO 112 I=1,NP3
      EMUL(I)=EMU(I)
      RT=RHO(I)*F(JK,I)**2/(F(JD,I)*EMUL(I)+1.0E-30)
      CDD=CD*EXP(-2.5/(1.0+RT/50.))
      EMUT(I)=CDD*RHO(I)*F(JK,I)*F(JK,I)/(F(JD,I)+1.0E-30)
      EMU(I)=EMU(I)+EMUT(I)
  112 AMU(I)=EMU(I)
C     ------------------------------------------------ TEST 10
  200 IF (ITEST) 202,201,202
  202 LAB(1)=6HTEST 1
      LAB(2)=6H0
      WRITE (6,100) LAB
      LAB(1)=6HEMU(I)
      LAB(2)=6H
      WRITE (6,100) LAB,(EMU(I),I=1,NP3)
  201 CONTINUE
C     ------------------- MODIFICATION OF EMU ARRAY
      DO 23 I=2,NP2
   23 EMU(I)=.5*(EMU(I+1)+EMU(I))
      DO 24 I=2,NP1
   24 EM U(I)=EMU(I)/(Y(I+1)-Y(I))
      IF (KRAD.EQ.0) GO TO 300
      DO 26 I=2,NP1
   26 EM U(I)=EM U(I)*.5*(R(I)+R(I+1))
  300 CONTINUE
      RETURN
C     ************************** SOURCE TERMS **********************
      ENTRY SOURCE
      IF (NV.NE.0) GO TO 500
C     ------ VELOCITY U
      DO 309 I=2,NP2
  309 US(I)=DPDX(I)*RDY(I)
      GO TO 6000
C     ----------------------- KINETIC HEATING.
  500 IF (NV.NE.JH) GO TO 1000
C     ------ TEMPORARY USE OF SD ARRAY.
      GO TO (303,304), NOVEL
  303 DO 305 I=1,NP3
      SU(I)=0.
  305 SD(I)=0.
      GO TO 306
  304 DO 30 I=2,NP2
   30 S D(I)=U(I)*U(I)
      DO 31 I=2,NP1
   31 S D(I)=EM U(I)*(S D(I+1)-S D(I))
      S D(1)=0.
      S D(NP2)=0.
      DO 32 I=2,NP2
      T=(1.-1./PREF(1))*.5
   32 SU(I)=(S D(I)-S D(I-1))*T
      DO 33 I=2,NP1
   33 SD(I)=0.
C     ---------------------------------------- TEST 11
  306 IF(ITEST) 302,301,302
```

```
  302 LAB(1)=6HTEST 1
      LAB(2)=1H1
      WRITE(6,100) LAB
      LAB(1)=6HSD(I
      LAB(2)=1H)
      WRITE(6,100) LAB,(SD(I),I=1,NP3)
      LAB(1)=6HSU(I
      LAB(2)=1H)
      WRITE(6,100) LAB,(SU(I),I=1,NP3)
  301 CONTINUE
      GO TO 6000
C ------------------------ SPECIES EQUATIONS --------------------------
 1000 DO 145 JJ=1,NSPM
      J=JLOC(JJ)
      IF (NV.EQ.J) GO TO 146
  145 CONTINUE
      GO TO 3500
  146 IF (INERT-1) 147,147,148
  147 DO 150 I=2,NP2
      SU(I)=0.
  150 SD(I)=0.
      GO TO 6000
  148 REWIND 4
      DO 152 I=2,NP2
      READ (4) TSOR
      DO 154 K=1,NSPM
      KK=K
      IF (NV.EQ.JLOC(K)) GO TO 155
  154 CONTINUE
  155 SU(I)=TSOR(KK)
  152 SD(I)=0.
      GO TO 6000
C     ----------        SWIRL VELOCITY     ------------------
 3500 IF (NV.NE.JVT) GO TO 4000
      DO 60 I=2,NP2
      SU(I)=0.0
   60 SD(I)=0.0
      GO TO 6000
C     -------------        TURBULENT KINETIC ENERGY      ------------------
 4000 IF (NV.NE.JK) GO TO 5000
      D22=Y(3)-Y(1)
      VT2=F(JVT,2)/(.75*R(2)+.25*R(3))
      VT3=F(JVT,3)/R(3)
      RK2=SQRT(F(JK,2))
      RK3=SQRT(F(JK,3))
      DUDY(2)=(U(3)-U(2))/D22
      DVTDY=(VT3-VT2)/D22
      DK2=(RK3-RK2)/D22
      GENR(2)=DUDY(2)**2+(DVTDY-VT2/(.75*R(2)+.25*R(3)))**2
C     ------------------------------
      DO 70 I=3,NP1
      D11=D22
      D22=Y(I+1)-Y(I)
      IF (I.EQ.NP1) D22=Y(NP3)-Y(NP1)
      D12=D11+D22
      DUDY(I)=D11*(U(I+1)-U(I))/(D12*D22)+D22*(U(I)-U(I-1))/(D12*D11)
      VT1=VT2
      VT2=VT3
      VT3=F(JVT,I+1)/R(I+1)
      IF (I.EQ.NP1) VT3=F(JVT,NP2)/(.75*R(NP2)+.25*R(NP1))
      DVTDY=D11*(VT3-VT2)/(D12*D22)+D22*(VT2-VT1)/(D12*D11)
      RK1=RK2
      RK2=RK3
      RK3=SQRT(F(JK,I+1))
      DRKDY=D11*(RK3-RK2)/(D12*D22)+D22*(RK2-RK1)/(D12*D11)
      GENR(I)=DUDY(I)**2+(DVTDY-VT2/R(I))**2
      SU(I)=EMUT(I)*GENR(I)
   70 SD(I)=-(RHO(I)*F(JD,I)+2.*EMUL(I)*DRKDY**2)/F(JK,I)
C -----------------------------
      DUDY(NP2)=(U(NP2)-U(NP1))/D22
      DVTDY=(VT3-VT2)/D22
      DKNP2=(RK3-RK2)/D22
      GENR(NP2)=DUDY(NP2)**2+(DVTDY-VT3/(.75*R(NP2)+.25*R(NP1)))**2
      F6=.75*F(JK,2)+.25*F(JK,3)
      F7=.75*F(JD,2)+.25*F(JD,3)
      SU(2)=EMUT(2)*GENR(2)
      SD(2)=-(RHO(2)*F7+2.*EMUL(2)*DK2**2)/F6
```

```
      F6=.75*F(JK,NP2)+.25*F(JK,NP1)
      F7=.75*F(JD,NP2)+.25*F(JD,NP1)
      SU(NP2)=EMUT(NP2)*GENR(NP2)
      SD(NP2)=-(RHO(NP2)*F7*2.*EMUL(NP2)*DKNP2**2)/F6
   76 DO 77 I=2,NP2
      SU(I)=SU(I)*0.5*RDY(I)
   77 SD(I)=SD(I)*0.5*RDY(I)
C     --------------------------------------------------     TEST 13
      IF (ITEST) 78,79,78
   78 LAB(1)=6HTEST 1
      LAB(2)=6H3
      WRITE (6,100) LAB
      LAB(1)=6HSU(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(SU(I),I=1,NP3)
      LAB(1)=6HSD(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(SD(I),I=1,NP3)
   79 CONTINUE
C     ---------------------
      GO TO 6000
C     ------------------      TURBULENCE DISSIPATION      -------------------
 5900 IF (NV.NE.JD) GO TO 6000
      D22=Y(3)-Y(2)
      DO 80 I=3,NP1
      C2E=C2
      IF (ISOLVE(JVT).EQ.0) GO TO 90
      D11=D22
      D22=Y(I+1)-Y(I)
      D12=D11+D22
      DRVTDY=D11*(F(JVT,I+1)-F(JVT,I))/(D12*D22)+D22*(F(JVT,I)-F(JVT,I-1
     * ))/(D12*D11)
      C2E=C2E+C2V*(F(JVT,I)/R(I)**3)*DRVTDY/(GENR(I)+1.0E-20)
      C2E=AMIN1(C2E,3.)
      C2E=AMAX1(C2E,1.)
   90 DUDYDY=(DUDY(I+1)-DUDY(I-1))/(Y(I+1)-Y(I-1))
      FACTOR=2.*EMUL(I)*EMUT(I)*DUDYDY*DUDYDY/RHO(I)
      SU(I)=C1*F(JD,I)*EMUT(I)*GENR(I)/F(JK,I)+FACTOR
   80 SD(I)=-C2E*F(JD,I)*RHO(I)/F(JK,I)
C     ------------------
      F6=.75*F(JK,2)+.25*F(JK,3)
      F7=.75*F(JD,2)+.25*F(JD,3)
      GO TO (81,82,82), KIN
   81 IF (RMI.GT.1.E-10) GO TO 82
      SU(2)=1.E30*CD75*F6**1.5/(YI*AK)
      SD(2)=-1.E30
      GO TO 83
   82 SU(2)=C1*F7*EMUT(2)*GENR(2)/F6
      SD(2)=-C2*F7*RHO(2)/F6
   83 F6=.75*F(JK,NP2)+.25*F(JK,NP1)
      F7=.75*F(JD,NP2)+.25*F(JD,NP1)
      GO TO (84,85,85), KEX
   84 IF (RME.LT.-1.E-10) GO TO 85
      SU(NP2)=1.E30*CD75*F6**1.5/(YE*AK)
      SD(NP2)=-1.E30
      GO TO 86
   85 SU(NP2)=C1*F7*EMUT(NP2)*GENR(NP2)/F6
      SD(NP2)=-C2*F7*RHO(NP2)/F6
   86 DO 87 I=2,NP2
      SU(I)=SU(I)*0.5*RDY(I)
   87 SD(I)=SD(I)*0.5*RDY(I)
C     --------------------------------------------------     TEST 14
      IF (ITEST) 88,89,88
   88 LAB(1)=6HTEST 1
      LAB(2)=6H4
      WRITE (6,100) LAB
      LAB(1)=6HSU(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(SU(I),I=1,NP3)
      LAB(1)=6HSD(I
      LAB(2)=6H)
      WRITE (6,100) LAB,(SD(I),I=1,NP3)
   89 CONTINUE
C     -----------
 6000 CONTINUE
      RETURN
  100 FORMAT(1H ,A6,A2,1P11E11.3/(9X,11E11.3))
```

```
                         END                                                          AD         220

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

    60      I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   197      I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
   206      I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
```

```
SUBROUTINE AUS        73/74    OPT=0 TRACE                 FTN 4.6+439        05/24/78  14.42.35        PAGE    1

      SUBROUTINE AUS
      COMMON/COMA/A(43),AJE(15),AJI(15),B(43),C(43),CSALFA,D(43),
     1 DPDF(43),DX,EMU(43),F(15,43),FS(3,43),IAX,IEND,IFIN,INDE(17),
     2 INDI(15),IOUT,ISTEP,ITEST,IUTRAP,JJ,JSW,JV,JT,KEX,KIN,KRAD,N,
     3 NO2,NE,NIVEL,NP1,NP2,NP3,OM(43),OMO(43),P(43),PFI,PR(15),
     4 PREF(15),PSIE,PSII,R(43),RHO(43),RU(43),RME,RMI,SC(43),SU(43),
     5 TAJE,TAJI,U(43),XS,XU,Y(43),YE,YI,PSWAL(43),RDY(43),ISOLVE(15),
     6 US(43),AMU(43),SUM1,SUM2,SUM3,SUM4,PDGSCN,FDIFI(15),FDIFE(15),
     7 SE(15),SI(15),JLOC(12),W(12),JH,JFU,JCO2,JCO,JOX,JH2O,JOH,JO,JHS,
     8 JH2,JN,JNO,JN2,JNT,JD,JK,JT,JRY,NSP,NSPM,ABSOR,SCATR,BOP(200),
     9 TEMP1,TEMP2,ISMAX,EFU,EO2,EH2O,EPD,EPR
      COMMON/COMB/AK,ALPG,EWALL,FR,H,HFU,INERT,MASSTR,MODEL,PRESS,
     1 UBAR,UFAC,C1,C2,CD,C2KT,AKFAC,ALFAC,ARCOM1,ARCOM2,PREXP1,PD75,
     2 PREXP2,CR1,CR2,MODER,MODCP,RATIO1,RATIO2,RATIO3,RATIO4,RATIO5,
     3 CX,HY,SXDLD,WFU,WCO2,WCO,WOX,WH2O,WOH,WO,WH,
     4 WH2,WN,WNO,WN2
C---------------------------------------------------------------------
C------------------------ 16 STEP REACTION SCHEME --------------------
C
C           CXHY + (X/2+FY/4) O2 = XCO + (FY/2)H2O + (1-F)(Y/2)H2
C                             CO + OH = CO2 + H
C                             CO + O2 = CO2 + O
C                   M +       CO + O  = CO2 + M
C                             CO + H2O = CO2 + H2
C                             O2 + H2 = OH + OH
C                             OH + H2 = H2O + H
C                             O2 + H  = OH + O
C                             O + H2  = OH + H
C                             O + H2O = OH + OH
C                   M +       H + H   = H2 + M
C                   M +       O + O   = O2 + M
C                   M +       O + H   = OH + M
C                             N + OH  = NO + H
C                            N2 + O   = NO + N
C                            O2 + N   = NO + O
C---------------------------------------------------------------------
C------------------------ DIMENSIONS AND DATA STATEMENTS -------------
      DIMENSION RDAT(3,16),FU(16),TSCR(16),GPT(16),RF(16),RB(16)
      DIMENSION FOR(16),DSOR(16)
      REAL KF(16),KB(16),LAB(2)
      DATA ((RDAT(I,J),I=1,3),J=2,16)/
     1 5.60E+11,  0.0, -1080.,
     2 2.55E+12,  0.0,-48000.,
     3 1.00E+15,  0.0, -4000.,
     4 2.50E+09,  .55,    0.0,
     5 [illegible]E+14,  0.0,-45000.,
     6 2.19E+13,  0.0, -5150.,
     7 2.24E+14,  0.0,-16800.,
     8 1.74E+13,  0.0, -9450.,
     9 5.75E+13,  0.0,-18000.,
     * 5.00E+18,-1.15,    0.0,
     1 4.70E+15, -.28,    0.0,
     2 5.30E+15,  0.0,  2780.,
     3 3.99E+14,  0.0,    0.0,
     4 [illegible]E+13,  0.1,-752[illegible].,
     5 6.43E+09,  1.0, -6250./
C---------------------------------------------------------------------
C
      READING 6
      IF (INERT.EQ.1) RETURN
      IF (ISTEP.GT.1) GO TO 5
      NFU=1
      NCO2=2
      NCO=3
      NO2=4
      NH2O=5
      NOH=6
      NO=7
      NH2=8
      NH=9
      NN=10
      NNO=11
      NN2=12
      CIX=1.0
      SMALL=1.E-20
      BCKGND=1.E-20
```

SUBROUTINE AUES   73/74   OPT=0 TRACE   FTN 4.6+439   08/24/78 14.42.35   PAGE   2

```
      RDAT(1,1)=PREXP1
      RDAT(2,1)=0.
      RDAT(3,1)=-ARCON1
    5 DO 5000 I=2,NP2
      SX=P(I)*9.8692E-06/(82.0575*FS(JT,I))
      DO 5995 J=1,16
 5995 KF(J)=RDAT(1,J)*FS(JT,I)**RDAT(2,J)*EXP(RDAT(3,J)/
     1  (1.987*FS(JT,I)))
      DO 620 K=2,NSP
  620 GRT(K)=GT(FS(JT,I),K)
      AFCTR=ALOG(82.06*FS(JT,I))
C ------- SUM GIBBS FREE ENERGY ---------
      KB(2)=GRT(NCO)+GRT(NOH)-GRT(NCO2)-GRT(NHS)
      KB(3)=GRT(NCO)+GRT(NO2)-GRT(NCO2)-GRT(NO)
      KB(4)=GRT(NCO)+GRT(NO)-GRT(NCO2)+AFCTR
      KB(5)=GRT(NCO)+GRT(NH2O)-GRT(NCO2)-GRT(NH2)
      KB(6)=GRT(NO2)+GRT(NH2)-2.*GRT(NOH)
      KB(7)=GRT(NOH)+GRT(NH2)-GRT(NH2O)-GRT(NHS)
      KB(8)=GRT(NO2)+GRT(NHS)-GRT(NOH)-GRT(NO)
      KB(9)=GRT(NO)+GRT(NH2)-GRT(NOH)-GRT(NHS)
      KB(10)=GRT(NO)+GRT(NH2O)-2.*GRT(NOH)
      KB(11)=2.*GRT(NHS)-GRT(NH2)+AFCTR
      KB(12)=2.*GRT(NC)-GRT(NO2)+AFCTR
      KB(13)=GRT(NO)+GRT(NHS)-GRT(NOH)+AFCTR
      KB(14)=GRT(NN)+GRT(NOH)-GRT(NNO)-GRT(NHS)
      KB(15)=GRT(NN2)+GRT(NO)-GRT(NNO)-GRT(NN)
      KB(16)=GRT(NO2)+GRT(NN)-GRT(NNO)-GRT(NO)
C -------- COMPUTE BACKWARD RATE CONSTANTS -----------
      DO 5990 J=2,16
 5990 KB(J)=KF(J)/EXP(KB(J))
C ------ SOME PRELIMINARIES ----------
 4150 RDK=RHO(I)/1000.
      RDK2=RDK*RDK
      KOUNT=0
C ------ COMPUTE FWD AND BKD REACTION RATES ---------
      DO 7875 JJ=1,NSPM
      J=JLOC(JJ)
 7875 FU(JJ)=F(J,I)
      FU(NN2)=FS(JN2,I)
      XUI=XU
 7880 KOUNT=KOUNT+1
      IF (KOUNT.LT.ISMAX) GO TO 5987
      IF (KOUNT.GT.ISMAX+15) STOP
C ----------------
      LAB(1)=6HAUS1
      LAB(2)=2H
      WRITE (6,990) LAB,I,ISTEP,KOUNT
      WRITE (6,980) LAB,XUI,XD,DXI
      WRITE (6,980) LAB,(TSOR(J),J=1,NSPM)
      WRITE (6,980) LAB,(  FU(J),J=1,NSPM)
C ------------------
 5987 DO 5980 J=1,NSP
      FU(J)=AMAX1(FU(J),BCKGND)
 5980 FDM(J)=FU(J)/W(J)
C  ****************          SOURCE TERM CALCULATION   ********************
C
      FH2O=AMAX1(BCKGND,FDM(NH2O))
      RF(1)=KF(1)*(FDM(NFU)**EFU)*(FDM(NO2)**EO2)*(FH2O**EH2O)*
     *  (RDK**ERO)*(P(I)/101315.)**EPR
      RF1=CR1*RDK*FDM(NFU)*F(JO,I)/(F(JK,I)+1.E-30)
      RF(1)=AMIN1(RF(1),RF1)
      RB(1)=0.0
      RF(2)=KF(2)*FDM(NCO)*FDM(NOH)*RDK2
      RB(2)=KB(2)*FDM(NCO2)*FDM(NHS)*RDK2
      RF(3)=KF(3)*FDM(NCO)*FDM(NO2)*RDK2
      RB(3)=KB(3)*FDM(NCO2)*FDM(NO)*RDK2
      RF(4)=KF(4)*SX*FDM(NCO)*FDM(NO)*RDK2
      RB(4)=KB(4)*SX*FDM(NCO2)*RDK
      RF(5)=KF(5)*FDM(NCO)*FDM(NH2O)*RDK2
      RB(5)=KB(5)*FDM(NCO2)*FDM(NH2)*RDK2
      RF(6)=KF(6)*FDM(NO2)*FDM(NH2)*RDK2
      RB(6)=KB(6)*FDM(NOH)*FDM(NOH)*RDK2
      RF(7)=KF(7)*FDM(NOH)*FDM(NH2)*RDK2
      RB(7)=KB(7)*FDM(NH2O)*FDM(NHS)*RDK2
      RF(8)=KF(8)*FDM(NO2)*FDM(NHS)*RDK2
      RB(8)=KB(8)*FDM(NOH)*FDM(NO)*RDK2
      RF(9)=KF(9)*FDM(NO)*FDM(NH2)*RDK2
```

```
      RB(7)=KB(7)*FDM(NOH)*FDM(NHS)*RDK2
      RF(10)=KF(10)*FDM(NO)*FDM(NH2O)*RDK2
      RB(10)=KB(10)*FDM(NOH)*FDM(NOH)*RDK2
      RF(11)=KF(11)*SX*FDM(NHS)*FDM(NHS)*RDK2
      RB(11)=KB(11)*SX*FDM(NH2)*RDK
      RF(12)=KF(12)*SX*FDM(NO)*FDM(NO)*RDK2
      RB(12)=KB(12)*SX*FDM(NO2)*RDK
      RF(13)=KF(13)*SX*FDM(NO)*FDM(NHS)*RDK2
      RB(13)=KB(13)*SX*FDM(NOH)*RDK
      RF(14)=KF(14)*FDM(NN)*FDM(NOH)*RDK2
      RB(14)=KB(14)*FDM(NNO)*FDM(NHS)*RDK2
      RF(15)=KF(15)*FDM(NN2)*FDM(NO)*RDK2
      RB(15)=KB(15)*FDM(NNO)*FDM(NN)*RDK2
      RF(16)=KF(16)*FDM(NO2)*FDM(NN)*RDK2
      RB(16)=KB(16)*FDM(NNO)*FDM(NO)*RDK2
C ------- CALCULATE SPECIES SOURCE TERMS --------
 5932 TSOR(NFU)=RB(1)-RF(1)
      TSOR(NCO2)=RF(2)-RB(2)+RF(3)-RB(3)+RF(4)-RB(4)+RF(5)-RB(5)
      TSOR(NCO)=RB(2)-RF(2)+RB(3)-RF(3)+RB(4)-RF(4)+RB(5)-RF(5)+
     *          CX*(RF(1)-RB(1))
      TSOR(NO2)=RB(3)-RF(3)+RB(6)-RF(6)+RB(8)-RF(8)+RF(12)-RB(12)+
     *          ((CX/2.+DIV*HY/4.)*(RB(1)-RF(1))
      TSOR(NH2O)=RB(5)-RF(5)+RF(7)-RB(7)+RB(10)-RF(10)+
     *          (DIV*HY/2.)*(RF(1)-RB(1))
      TSOR(NOH)=RB(2)-RF(2)+2.*(RF(6)-RB(6))+RB(7)-RF(7)+RF(8)-RB(8)+
     *          RF(9)-RB(9)+2.*(RF(10)-RB(10))+RF(13)-RB(13)
      TSOR(NO)=RF(3)-RB(3)+RB(4)-RF(4)+RF(8)-RB(8)+RB(9)-RF(9)+
     *          RB(10)-RF(10)+2.*(RB(12)-RF(12))+RB(13)-RF(13)
      TSOR(NHS)=RF(2)-RB(2)+RF(7)-RB(7)+RB(8)-RF(8)+RF(9)-RB(9)+
     *          2.*(RB(11)-RF(11))+RB(13)-RF(13)
      TSOR(NH2)=((1.-DIF)*HY/2.)*(RF(1)-RB(1))+RF(5)-RB(5)+RB(6)-RF(6)+
     *          RB(7)-RF(7)+RB(9)-RF(9)+RF(11)-RB(11)
      TSOR(NO2)=TSOR(NO2)+RB(16)-RF(16)
      TSOR(NOH)=TSOR(NOH)+RB(14)-RF(14)
      TSOR(NO)=TSOR(NO)+RB(15)-RF(15)+RF(16)-RB(16)
      TSOR(NHS)=TSOR(NHS)+RF(14)-RB(14)
      TSOR(NN)=RB(14)-RF(14)+RF(15)-RB(15)+RB(16)-RF(16)
      TSOR(NNO)=RF(14)-RB(14)+RF(15)-RB(15)+RF(16)-RB(16)
      TSOR(NN2)=RB(15)-RF(15)
      DSOR(NFU)=0.
      DSOR(NCO2)= KB(2)*FDM(NHS)*RDK2       +  KB(3)*FDM(NO)*RDK2      +
     1            KB(4)*SX*RDK              +  KB(5)*FDM(NH2)*RDK2
      DSOR(NCO)=  KF(2)*FDM(NOH)*RDK2       +  KF(3)*FDM(NO2)*RDK2     +
     1            KF(4)*SX*FDM(NO)*RDK2     +  KF(5)*FDM(NH2O)*RDK2
      DSOR(NO2)=  KF(3)*FDM(NCO)*RDK2       +  KF(6)*FDM(NH2)*RDK2     +
     1            KF(8)*FDM(NHS)*RDK2       +  KB(12)*SX*RDK           +
     2            KF(16)*FDM(NN)*RDK2
      DSOR(NH2O)= KF(5)*FDM(NCO)*RDK2       +  KB(7)*FDM(NHS)*RDK2     +
     1            KF(10)*FDM(NO)*RDK2
      DSOR(NOH)=  KF(2)*FDM(NCO)*RDK2       +  2.*KB(6)*FDM(NOH)*RDK2  +
     1            KF(7)*FDM(NH2)*RDK2       +  KB(8)*FDM(NO)*RDK2      +
     2            KB(9)*FDM(NHS)*RDK2       +  2.*KB(10)*FDM(NOH)*RDK2 +
     3            KB(13)*SX*RDK             +  KF(14)*FDM(NN)*RDK2
      DSOR(NO)=   KB(3)*FDM(NCO2)*RDK2      +  KF(4)*SX*FDM(NCO)*RDK2  +
     1            KB(8)*FDM(NOH)*RDK2       +  KF(9)*FDM(NH2)*RDK2     +
     2            KF(10)*FDM(NH2O)*RDK2     +  2.*KF(12)*SX*FDM(NO)*RDK2+
     3            KF(13)*SX*FDM(NHS)*RDK2   +  KF(15)*FDM(NN2)*RDK2    +
     4            KB(16)*FDM(NNO)*RDK2
      DSOR(NHS)=  KB(2)*FDM(NCO2)*RDK2      +  KB(7)*FDM(NH2O)*RDK2    +
     1            KF(8)*FDM(NO2)*RDK2       +  KB(9)*FDM(NOH)*RDK2     +
     2         2.*KF(11)*SX*FDM(NHS)*RDK2   +  KF(13)*SX*FDM(NO)*RDK2  +
     3            KB(14)*FDM(NNO)*RDK2
      DSOR(NH2)=  KB(5)*FDM(NCO2)*RDK2      +  KF(6)*FDM(NO2)*RDK2     +
     1            KF(7)*FDM(NOH)*RDK2       +  KF(9)*FDM(NO)*RDK2      +
     2            KB(11)*SX*RDK
      DSOR(NN)=   KF(14)*FDM(NOH)*RDK2      + KB(15)*FDM(NNO)*RDK2     +
     1            KF(16)*FDM(NO2)*RDK2
      DSOR(NNO)=  KB(14)*FDM(NHS)*RDK2      +  KB(15)*FDM(NN)*RDK2     +
     1            KB(16)*FDM(NO)*RDK2
      DSOR(NN2)=  KF(15)*FDM(NO)*RDK2
C ----- CONVERT SOURCE TERMS TO PROPER UNITS ------
      DO 5970 J=1,NSP
      TSOR(J)=TSOR(J)*RDY(I)*1000.*W(J)
      DSOR(J)=DSOR(J)*RDY(I)*1000.*W(J)
 5970 CONTINUE
C --------- DETERMINE STEP SIZE --------------
      DXI=DX
```

```
      HPBOM=PEI*BOM(I)/2.
      DO 8000 J=1,NSP
      IF (ABS(TSOR(J)).LT.SMALL) GO TO 8000
      DF=AMAX1(TERM2,TERM1*FM(J))
      DXI=AMIN1(DXI,DF*HPBOM/ABS(TSOR(J)))
 8000 CONTINUE
      XDI=XUI+DXI
      IF (XDI.GT.X0) DXI=X0-XUI
      IF (DXI.GT.0.) GO TO 8010
C ------------------------
      LAB(1)=6HAUS2
      LAB(2)=2H
      WRITE (6,990) LAB,I,ISTEP,KOUNT
      WRITE (6,980) LAB,DX,XUI,XDI,X0,DXI
  980 FORMAT (1H0,A6,A2,1P11E11.3/(9X,11E11.3))
  990 FORMAT (1H0,A6,A2,1I1I1)
      STOP
C -------------------------
 8010 PXBOM=PEI*BOM(I)/DXI
C ------------ SOLVE FOR DOWNSTREAM SPECIE VALUES ---------
      DO 7995 J=1,NSP
      FU(J)=(PXBOM*FU(J)+2.*(TSOR(J)+BSOR(J)*FDM(J)))/(PXBOM+2.*BSOR(J)/
     1 W(J))
 7995 CONTINUE
      XUI=XDI
      IF (XUI.LT.XD) GO TO 7000
      PXBOM=PEI*BOM(I)/DX
      DO 78 K=1,NSPM
      J=JLOC(K)
   78 TSOR(K)=.5*PXBOM*(FU(K)-F(J,I))
      WRITE (4) TSOR
 6000 CONTINUE
      RETURN
      END
```

```
      FUNCTION GASP (TT,I)
      DIMENSION AM(7,12),AL(7,12),W(12)
C
C     SPECIES ORDER - FUEL,CO2,CO,O2,H2O,OH,O,H,H2,N,NO,N2
C
      DATA ((AM(I,J),I=1,7),J=1,6)/
     1 0.26845936E+02, 0.46470050E-01,-0.22967813E-04, 0.48494616E-08,
     2-0.37080219E-12,-0.40857112E+05, 0.             ,
     3  .44608041E+01,  .30981719E-02, -.12392571E-05,  .22741325E-09,
     4 -.15525954E-13, -.48961442E+05, -.98635982E+00,
     5  .29840696E+01,  .14891390E-02, -.57899684E-06,  .10364577E-09,
     6 -.69353550E-14, -.14245228E+05,  .63479156E+01,
     7  .36219535E+01,  .73618264E-03, -.19652228E-06,  .36201558E-10,
     8 -.28945627E-14, -.12019825E+04,  .36150960E+01,
     9  .27167633E+01,  .29451374E-02, -.80224374E-06,  .10226682E-09,
     * -.48472145E-14, -.29905826E+05,  .66305671E+01,
     1  .29131230E+01,  .95418248E-03, -.19084327E-06,  .12730795E-10,
     2  .24803941E-15,  .39647060E+04,  .54288735E+01/
C
      DATA ((AM(I,J),I=1,7),J=7,12)/
     1  .25420596E+01, -.27550619E-04, -.31028033E-08,  .45510674E-11,
     2 -.43680515E-15,  .29230803E+05,  .49203080E+01,
     3  .25000000E+01, 0.             , 0.             , 0.             ,
     4 0.             ,  .25471627E+05, -.46011763E+00,
     5  .31001901E+01,  .51119464E-03,  .52644210E-07, -.34909973E-10,
     6  .36945345E-14, -.87738042E+03, -.19629421E+01,
     7  .24502682E+01,  .10661458E-03, -.74653373E-07,  .18796524E-10,
     8 -.10259839E-14,  .56116040E+05,  .44487581E+01,
     9  .31890000E+01,  .13382281E-02, -.52899318E-06,  .95919332E-10,
     * -.64847932E-14,  .98283290E+04,  .67458126E+01,
     1  .28963194E+01,  .15154866E-02, -.57235277E-06,  .99807393E-10,
     2 -.65223555E-14, -.90586184E+03,  .61615148E+01/
C
      DATA ((AL(I,J),I=1,7),J=1,6)/
     1 0.57799475E+01, 0.50561458E-01, 0.51144255E-04,-0.94958140E-07,
     2 0.39603875E-10,-0.29323482E+05, 0.             ,
     3  .24007797E+01,  .87350957E-02, -.66070878E-05,  .20021861E-08,
     4  .63274039E-15, -.48377527E+05,  .96951457E+01,
     5  .37100928E+01, -.16190964E-02,  .36923594E-05, -.20319674E-08,
     6  .23953344E-12, -.14356310E+05,  .29555351E+01,
     7  .36255985E+01, -.18782184E-02,  .70554544E-05, -.67635137E-08,
     8  .21555993E-11, -.10475226E+04,  .43052778E+01,
     9  .40701275E+01, -.11084499E-02,  .41521180E-05, -.29637404E-08,
     *  .80702103E-12, -.30279722E+05, -.32270046E+00,
     1  .38365518E+01, -.10702014E-02,  .94849757E-06,  .18713972E-09,
     2 -.22571094E-12,  .36412823E+04,  .49370009E+00/
C
      DATA ((AL(I,J),I=1,7),J=7,12)/
     1  .29464287E+01, -.16381665E-02,  .24210316E-05, -.16028432E-08,
     2  .38906964E-12,  .29147644E+05,  .29639949E+01,
     3  .25000000E+01, 0.             , 0.             , 0.             ,
     4 0.             ,  .25471627E+05, -.46011762E+00,
     5  .30574451E+01,  .26765200E-02, -.58099162E-05,  .55210391E-08,
     6 -.18122739E-11, -.98890474E+03, -.22997056E+01,
     7  .25030714E+01, -.21800181E-04,  .54205287E-07, -.56475602E-10,
     8  .20999044E-13,  .56098904E+05,  .41675764E+01,
     9  .40459521E+01, -.34181783E-02,  .79819190E-05, -.61139316E-08,
     *  .15919076E-11,  .97453934E+04,  .29974988E+01,
     1  .36748261E+01, -.12081500E-02,  .23240102E-05, -.63217559E-09,
     2 -.22577253E-12, -.10611588E+04,  .23580424E+01/
C
      DATA W/44.,44.,28.,32.,18.,17.,16.,1.,2.,14.,30.,28./,KOUNT/0/
      DATA TLIM/1500./
C     ****************************************************************
      ENTRY GTT
      T=TT
      IF (T.LT.1000.) GO TO 10
      ARG=AM(1,I)*(1.-ALOG(T))+AM(6,I)/T-(AM(7,I)+T*(AM(2,I)/2.+T*(AM(3,
     1I)/6.+T*(AM(4,I)/12.+T*AM(5,I)/20.))))
      GO TO 15
   10 ARG=AL(1,I)*(1.-ALOG(T))+AL(6,I)/T-(AL(7,I)+T*(AL(2,I)/2.+T*(AL(3,
     1I)/6.+T*(AL(4,I)/12.+T*AL(5,I)/20.))))
   15 GASP=ARG
      RETURN
C     ****************************************************************
      ENTRY CPOR
      T=TT
```

```
FUNCTION GASP        73/74    OPT=0 TRACE                    FTN 4.6+439       08/24/78  14.42.35        PAGE    2

      IF (I.EQ.1) T=AMIN1(T,TLIM)
      IF (T.LT.1000.) GO TO 20
      ARG=AM(1,I)+T*(AM(2,I)+T*(AM(3,I)+T*(AM(4,I)+T*AM(5,I))))
      GO TO 25
   20 ARG=AL(1,I)+T*(AL(2,I)+T*(AL(3,I)+T*(AL(4,I)+T*AL(5,I))))
   25 GASP=ARG*1.987*4184./W(I)
      RETURN
C     ****************************************************************
      ENTRY HOR
      T=TT
      IF (I.EQ.1) T=AMIN1(T,TLIM)
      IF (T.LT.1000.) GO TO 30
      ARG=AM(6,I)+T*(AM(1,I)+T*(AM(2,I)/2.+T*(AM(3,I)/3.+T*(AM(4,I)/4.+T
     1*AM(5,I)/5))))
      GO TO 35
   30 ARG=AL(6,I)+T*(AL(1,I)+T*(AL(2,I)/2.+T*(AL(3,I)/3.+T*(AL(4,I)/4.+T
     1*AL(5,I)/5))))
   35 GASP=ARG*1.987*4184./W(I)
      IF (TT.LT.TLIM.OR.I.NE.1) RETURN
      CPI=AM(1,I)+T*(AM(2,I)+T*(AM(3,I)+T*(AM(4,I)+T*AM(5,I))))
      ARG=ARG+CPI*(TT-T)/W(I)
      GASP=ARG*1.987*4184./W(I)
      RETURN
C     ****************************************************************
      ENTRY COEF
      KOUNT=KOUNT+1
      IF (KOUNT.EQ.2) GO TO 40
      W(I)=TT
      GASP=W(I)
      RETURN
   40 HFU=TT
      AM(6,I)=HFU/1.987
      AL(6,I)=[illegible]FU/1.987
      GASP=AL([illegible],I)
      RETURN
      END
```

```
      SUBROUTINE STRIDE(ISW)                                             ST      2
      COMMON/COMA/A(43),AJE(15),AJI(15),B(43),C(43),CSALFA,D(43),        COMA    2
     1 DPDX(43),DX,EMU(43),F(15,43),FS(3,43),IAX,IEND,IFIN,INDE(15),     COMA    3
     2 INDI(15),IOUT,ISTEP,ITEST,INTRAP,JS,JSU,JV,JY,KEX,KIN,KRAD,N,     COMA    4
     3 ND2,NF,NOVEL,NP1,NP2,NP3,OM(43),OMD(43),P(43),PEI,PR(15),         COMA    5
     4 PREF(15),PSIE,PSII,R(43),RHO(43),RU(43),RME,RMI,SD(43),SU(43),    COMA    6
     5 TAUE,TAUI,U(43),XD,XU,Y(43),YE,YI,PSWRL(43),RDY(43),ISOLVE(15),   COMA    7
     6 US(43),AMU(43),SUM1,SUM2,SUM3,SUM4,PDESCN,FDIFI(15),FDIFE(15),    COMA    8
     7 GE(15),GI(15),JLOC(12),V(12),JH,JFU,JCO2,JCO,JNX,JH2O,JON,JO,JHS, COMA    9
     8 JN2,JN,JNO,JH2,JVT,JB,JK,JT,JRY,NSP,NSPM,ABSOR,SCATR,BOM(200),    COMA   10
     9 TERM1,TERM2,ISMAX,EPU,EO2,EH2O,ERO,EPR                            COMA   11
C/--------------- SUBROUTINE FOR PROGRAM GENMIX 4A ------------------   ST      4
C/ THIS SUBROUTINE PERFORMS THE SAME OPERATIONS AS THE ONE IN GENMIX4A  ST      5
C  BUT MORE ECONOMICALLY. THE A,B,C ARRAYS ARE ONE-DIMENSIONAL. SOME    ST      6
C  OFTEN USED FUNCTIONS OF OM ARE STORED, AND A D ARRAY SAVES           ST      7
C  UNNECESSARY ARITHMETIC IN THE TDMA OPERATION.                        ST      8
C--------------------------------------------------------------------  ST      9
      DIMENSION AMLPT(43),BOMT3(43),PBOM(43),PGOM(43),THLPT(43)         ST     10
      DIMENSION OMPOM(200)                                              ST     11
      DIMENSION TMP3FF(15),TTPF(15),TIFF(15)                            ST     12
      DIMENSION IKAS(15)                                                ST     13
      DATA IKAS/15*0/,KASU/0/                                           NA      6
C                                                                       ST     15
      GO TO (1000,2000,3000,4030), ISW                                  ST     16
C                                                                       ST     17
C*************************************  S T R I D E 1  ************   ST     18
 1000 IF(ISTEP) 1003,1003,1100                                          ST     19
 1003 OMI=.5*OM(3)                                                      ST     20
      OME=.5*(1.-OM(NP1))                                               ST     21
      DO 1002 I=2,NP2                                                   ST     22
      BOM(I)=OM(I+1)-OM(I-1)                                            ST     23
      BOMT3(I)=3.*BOM(I)                                                ST     24
      OMPOM(I)=OM(I)+OM(I+1)                                            ST     25
 1002 OMD(I)=OM(I+1)-OM(I)                                              ST     26
      OMD(1)=BOM(2)                                                     ST     27
      BPE=1.                                                            ST     28
      BPI=1.                                                            ST     29
      Y(1)=0.                                                           ST     30
      IF(KRAD.EQ.1) GO TO 1100                                          ST     31
      DO 1001 I=1,NP3                                                   ST     32
 1001 R(I)=1.                                                           ST     33
      R25=1.                                                            ST     34
      RN15=1.                                                           ST     35
      IF(ITEST.NE.0) WRITE(6,9010) (R(I),I=1,NP3),R25,RN15              ST     36
C--------------------------- CALCULATION OF RHO*U *S ---------------   ST     37
 1100 DO 1101 I=1,NP3                                                   ST     38
      IF(RHO(I).GT.0.) GO TO 1101                                       ST     39
      WRITE(6,1108) RHO(I),I,RHO(I)                                     ST     40
 1108 FORMAT(36H ********** NEGATIVE OR ZERO RHO(I)=,1PE11.3,6H AT I=,  ST     41
     1 I3,6X,21HSET TO ABS OF RHO(I)=,E11.3,17H ******** STRIDE1)       ST     42
      RHO(I)=ABS(RHO(I))                                                ST     43
 1101 RU(I)=RHO(I)*U(I)                                                 ST     44
      RU3=RU(3)                                                         ST     45
      RUN1=RU(NP1)                                                      ST     46
      DO 1102 I=2,NP1                                                   ST     47
 1102 RU(I)=.5*(RU(I)+RU(I+1))                                          ST     48
      IF(ITEST.NE.0) WRITE(6,9010) (RU(I),I=1,NP3),RUN1,RU3,PEI         ST     49
C--------------------------- CALCULATION OF Y *S AND R *S ----------   ST     50
C  --------------------------------------- Y*S FOR PLANE GEOMETRY      ST     51
      YI=PEI*OMI/(BPI*RU(2))                                            ST     52
      Y(3)=YI+PEI*OM(3)/(RU(2)+RU3)                                     ST     53
      Y(2)=2.*YI-Y(3)                                                   ST     54
      DO 1103 I=4,NP1                                                   ST     55
 1103 Y(I)=Y(I-1)+PEI*OMD(I-1)/RU(I-1)                                  ST     56
      YN15=Y(NP1)+PEI*OMD(NP1)/(RU(NP1)+RUN1)                           ST     57
      YE=PEI*OME/(BPE*RU(NP1))                                          ST     58
      Y(NP3)=YN15+YE                                                    ST     59
      Y(NP2)=2.*YN15-Y(NP1)                                             ST     60
      IF(KRAD.EQ.0) RETURN                                              ST     61
C  ----------------------- Y*S AND R*S FOR AXISYMMETRICAL GEOMETRY      ST     62
      IF(CSALFA.EQ.0.) GO TO 1110                                       ST     63
C  --------------------------------------- CSALFA NE ZERO               ST     64
      COSD2=.5*CSALFA                                                   ST     65
      IF(R(1).NE.0.) GO TO 1105                                         ST     66
C----------------------------------------- R(1)=0.                      ST     67
      DO 1106 I=2,NP3                                                   ST     68
      Y(I)=SQRT(ABS(Y(I)/COSD2))                                        ST     69
```

```
 1106 R(I)=Y(I)*CSALFA
      YI=SQRT(ABS(YI/COSD2))
      YN15=SQRT(ABS(YN15/COSD2))
      GO TO 1107
C     ----------------------------------------- R(1) NE 0.
 1105 R1D2=.5*R(1)
      R1D2SQ=R1D2*R1D2
      DO 1104 I=2,NP3
      Y(I)=Y(I)/(R1D2+SQRT(ABS(R1D2SQ+COSD2*Y(I))))
 1104 R(I)=R(1)+Y(I)*CSALFA
      YI=YI/(R1D2+SQRT(ABS(R1D2SQ+COSD2*YI)))
      YN15=YN15/(R1D2+SQRT(ABS(R1D2SQ+COSD2*YN15)))
 1107 R25=R(1)+YI*CSALFA
      RN15=R(1)+YN15*CSALFA
      YE=Y(NP3)-YN15
      RETURN
C     ----------------------------------------- CSALFA EQ ZERO
 1110 DO 1111 I=2,NP3
      Y(I)=Y(I)/R(1)
 1111 R(I)=R(1)
      YI=YI/R(1)
      YN15=YN15/R(1)
      R25=R(1)
      RN15=R(1)
      YE=Y(NP3)-YN15
      RETURN
C****************************************** S T R I D E 2 ****************
C     -------------------------------- PRELIMINARIES FOR COEFFICIENTS
 2000 PX=PEI/DX
      P08=.125*PX
      P04=P08+P08
      G=RMI-RME
      ARMI=ABS(RMI)
      ARME=ABS(RME)
      G04=.25*G
      PG=PX*G
      PG08=.125*PG
      PG04=PG08+PG08
      RMID2=.5*RMI
      DO 2004 I=2,NP2
      PBOM(I)=PX*BOM(I)
 2004 PGOM(I)=PG04*OMB(I)
      P4OMP=P04*BOM(2)
C     ----------------------------------------- GRID POINT 2
C---------------------------------------------- TAUI, BPI, TI
      IF(KIN.NE.1) GO TO 2001
      CALL WF(5,1,BPI,TI,TAUI)
      GO TO 2002
 2001 TI=0.
      IF(KRAD.EQ.0) BPI=.33333+.66667*RU(1)/RU(2)
      IF(KRAD.EQ.1) BPI=(R(1)*(5.*RU(1)+RU(2))+3.*R25*
     1                 (RU(1)+RU(2)))/6./(R(1)+R25)/RU(2)
 2002 DO 2700 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 2700
      IF (KIN.NE.1) GO TO 2705
      CALL WF (J,1,FDIFI(J),TIFF(J),GI(J))
      IF (INDI(J).EQ.2) GO TO 2700
      AJI(J)=GI(J)*(F(J,1)-.5*(F(J,2)+F(J,3))-FDIFI(J))
      GO TO 2700
 2705 TIFF(J)=0.
      FDIFI(J)=0.
 2700 CONTINUE
C     ----------------------------------------- GRID POINT NP2
C---------------------------------------------- TAUE, BPE, TNP3
 2304 IF(KEX.NE.1) GO TO 2003
      CALL WF(5,NP3,BPE,TNP3,TAUE)
      GO TO 2310
 2003 TNP3=0.
      IF(KRAD.EQ.0) BPE=.33333+.66667*RU(NP3)/RU(NP1)
      IF(KRAD.EQ.1) BPE=(R(NP3)*(5.*RU(NP3)+RU(NP1))+3.*RN15*
     1                (RU(NP3)+RU(NP1)))/6./(R(NP3)+ RN15)/RU(NP1)
 2310 DO 2720 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 2720
      IF (KEX.NE.1) GO TO 2730
      CALL WF(J,NP3,FDIFE(J),TNP3*F(J),GE(J))
      IF (INDE(J).EQ.2) GO TO 2720
      AJE(J)=GE(J)*(.5*(F(J,NP2)+F(J,NP1))+FDIFE(J)-F(J,NP3))
```

```
      GO TO 2720                                                    ST   147
 2730 TMP3FF(J)=0.                                                  ST   148
      FGIFF(J)=0.                                                   ST   149
 2720 CONTINUE                                                      ST   150
      RETURN                                                        ST   151
C************************************  S T R I D E 3  **************** ST   152
 3000 CALL SOURCE(0)                                                ST   153
C     ------------------  BOUNDARY COEFFICIENTS FOR VELOCITY        ST   154
C     -------  GRID POINT 2 COEFFICIENTS  ------------              ST   155
      AKASU=KASU                                                    MM     7
      HLP=RMID2-GD4*DMPOM(2)                                        ST   156
      AHLP=ABS(HLP)                                                 ST   157
      THLP=HLP+HLP                                                  ST   158
      THLPT(2)=THLP                                                 ST   159
      TP=EM U(2)                                                    ST   160
      TTP=TP+AHLP+ABS(TP-AHLP)                                      ST   161
      A(2)=TTP-THLP-T1-PGOM(2)*AKASU                                MM     8
      B(2)=2.*T1+RMI+ARMI                                           ST   163
      C(2)=P4OMP*(3.*U(2)+U(3))-US(2)                               ST   164
      IF (KASU.EQ.0) C(2)=4.*P4OMP*U(2)-US(2)                       MM     9
      D(2)=A(2)+B(2)+PBOM(2)                                        ST   165
C     -------  GRID POINT NP2 COEFFICIENTS  ------------            ST   166
      HLM=RMID2-GD4*DMPOM(NP1)                                      ST   167
      AHLM=ABS(HLM)                                                 ST   168
      THLM=HLM+HLM                                                  ST   169
      THLPT(NP2)=THLM                                               ST   170
      TM=EM U(NP1)                                                  ST   171
      TTM=TM+AHLM+ABS(TM-AHLM)                                      ST   172
      P4OMM=PD4*BOM(NP2)                                            ST   173
      A(NP2)=2.*TMP3-RME+ARME                                       ST   174
      A(NP2)=TTM+THLM-TMP3-PGOM(NP1)*AKASU                          MM    10
      C(NP2)=P4OMM*(3.*U(NP2)+U(NP1))-US(NP2)                       ST   176
      IF (KASU.EQ.0) C(NP2)=4.*P4OMM*U(NP2)-US(NP2)                 MM    11
      D(NP2)=A(NP2)+B(NP2)+PBOM(NP2)                                ST   177
C     -------  MID-STREAM COEFFICIENTS  ----------                  ST   178
      DO 3005 I=3,NP1                                               ST   179
      THLM=THLP                                                     ST   180
      HLP=RMID2-GD4*DMPOM(I)                                        ST   181
      THLP=HLP+HLP                                                  ST   182
      THLPT(I)=THLP                                                 ST   183
      AHLP=ABS(HLP)                                                 ST   184
      AHLPT(I)=AHLP                                                 ST   185
      TTM=TTP                                                       ST   186
      TP=EM U(I)                                                    ST   187
      TTP=TP+AHLP+ABS(TP-AHLP)                                      ST   188
      A(I)=TTP-THLP-PGOM(I)*AKASU                                   MM    12
      B(I)=TTM+THLM-PGOM(I-1)*AKASU                                 MM    13
      C(I)=PD4*(BOMT3(I)*U(I)+DMD(I)*U(I+1)+DMD(I-1)*U(I-1))-US(I)  ST   191
      IF (KASU.EQ.0) C(I)=4.*PD4*BOM(I)*U(I)-US(I)                  MM    14
      D(I)=A(I)+B(I)+PBOM(I)                                        ST   192
 3005 CONTINUE                                                      ST   193
      GO TO (3021,3020), NOVEL                                      ST   194
 3020 IF(ITEST) 3900,3905,3900                                      ST   195
 3900 WRITE(5,3901) (A(I),I=2,NP2)                                  ST   196
      WRITE(6,3902) (B(I),I=2,NP2)                                  ST   197
      WRITE(6,3903) (C(I),I=2,NP2)                                  ST   198
      WRITE(6,3904) (D(I),I=2,NP2)                                  ST   199
 3901 FORMAT(7H  A(I) ,1P11E11.3/(7X,11E11.3))                      ST   200
 3902 FORMAT(7H  B(I) ,1P11E11.3/(7X,11E11.3))                      ST   201
 3903 FORMAT(7H  C(I) ,1P11E11.3/(7X,11E11.3))                      ST   202
 3904 FORMAT(7H  D(I) ,1P11E11.3/(7X,11E11.3))                      ST   203
 3905 CONTINUE                                                      ST   204
C---------------------------                  -------------------- ST   205
      IF(KIN.EQ.2.AND.RU(1).NE.0.) U(1)=U(1)-DPDX(1)*DX/RU(1)       ST   206
      IF(KEX.EQ.2.AND.RU(NP3).NE.0.) U(NP3)=U(NP3)-DPDX(NP3)*DX/RU(NP3) ST 207
C---------------------------  SOLVE FOR DOWNSTREAM U'S  ----------- ST   208
      B(2)=(B(2)*U(1)+C(2))/D(2)                                    ST   209
      A(2)=A(2)/D(2)                                                ST   210
      DO 3048 I=3,NP2                                               ST   211
      T=D(I)-B(I)*A(I-1)                                            ST   212
      A(I)=A(I)/T                                                   ST   213
 3048 B(I)=(B(I)*B(I-1)+C(I))/T                                     ST   214
      DO 3050 IDASH=2,NP2                                           ST   215
      I=N+4-IDASH                                                   ST   216
      U(I)=A(I)*U(I+1)+B(I)                                         ST   217
C     ---------------------------------  TEST FOR NEGATIVE U'S      ST   218
C/IUTPAP=0,NO ACTION/ .GT.0,SET TO 1.E-30/ .GT.1,IFIN=-1/ .GT.2,ITEST=1/ ST 219
```

```
      IF(IUTRAP.EQ.0.OR.I.EQ.2.OR.I.EQ.NP2) GO TO 3050
      IF(U(I)) 3046,3046,3050
 3046 J=ISTEP+1
      WRITE(6,3047) U(I),I,J
 3047 FORMAT(25H ********** U (LE ZERO) =,1PE10.3,6H AT I=,I3,
     1 8H, ISTEP=,I6,34H, SET U TO 1.E-30 ******** STRIDE3)
      U(I)=1.E-30
      IFIN=-IUTRAP/2
      ITEST=IUTRAP/3
 3050 CONTINUE
C     ---------------------------------------------------
      IF(KIN.EQ.3) U(1)=.5*(U(2)+U(3))
      IF(KEX.EQ.3)U(NP3)=.5*(U(NP1)+U(NP2))
 3021 IF (ITEST) 3011,3014,3011
 3011 WRITE(6,3012) (U(I),I=1,NP3)
 3012 FORMAT(3H U ,6X,1P11E11.3/(9X,11E11.3))
C     ---------------------------------------------
C     ---------------  SOLVE FOR DOWN STREAM F*S   ------------------
 3014 DO 3321 J=1,NF
      IF (ISOLVE(J).EQ.0) GO TO 3321
      AKAS=FLOAT(IKAS(J))
C     -------   COMPUTE SOURCE TERMS   ---------
      CALL SOURCE(J)
C     --------   GRID POINT 2   ---------
      TP=EM U(2)
      TPF2=TP/PREF(J)
      THLP=THLPT(2)
      AHLP=.5*ABS(THLP)
      TTPF(J)=TPF2+AHLP+ABS(TPF2-AHLP)
      T1F=T1FF(J)
      IF (KIN.NE.1) GO TO 2302
      IF(INDI(J).EQ.2) GO TO 2303
CC    ------------   EDGE VALUE SPECIFIED   ------------
 2302 A(2)=TTPF(J)-THLP-T1F-(PGOM(2)-.5*SD(2))*AKAS
      B(2)=2.*T1F+RMI*ARMI
      D(2)=A(2)+B(2)+PBOM(2)-2.*SD(2)
      IF (J.NE.JVT) GO TO 510
      RP=.5*(R(2)+R(3))
      ATP=2.*(RP/R(3))**2
      AT1=(R(1)/RP)**2
      DTP=2.*(RP/(.75*R(2)+.25*R(3)))**2
      A(2)=TTPF(J)*ATP-THLP-T1F*AT1-(PGOM(2)-.5*SD(2))*AKAS
      TT=3.*PGOM(2)-1.5*SD(2)
      IF (IKAS(J).EQ.0) TT=4.*PGOM(2)-2.*SD(2)
      D(2)=TTPF(J)*DTP+T1F+THLP+TT
  510 T=-T1F*FDIFI(J)
      GO TO 2305
C     ---------------   EDGE FLUX SPECIFIED   ------------
 2303 A(2)=TTPF(J)-THLP-(PGOM(2)-.5*SD(2))*AKAS
      B(2)=0.
      D(2)=A(2)+PBOM(2)-2.*SD(2)+RMI*2.
      T=RMI*F(J,1)+AJI(J)*R(I)
 2305 TT=3.*F(J,2)-F(J,3)
      IF (IKAS(J).EQ.0) TT=4.*F(J,2)
      C(2)=PGOMP*T.+2.*(T+SU(2))
 2300 CONTINUE
C     -----------   GRID POINT NP2   ---------
      TM=EM U(NP1)
      TMF=TM/PREF(J)
      THLM=THLPT(NP2)
      AHLM=.5*ABS(THLM)
      TTMF=TMF+AHLM+ABS(TMF-AHLM)
      TMP3F=TMP3FF(J)
      IF (KEX.NE.1) GO TO 2312
      IF(INDE(J).EQ.2) GO TO 2313
C     ---------------   EDGE VALUE SPECIFIED   ---------
 2312 A(NP2)=2.*TMP3F-RME+ARME
      B(NP2)=TTMF+THLM-TMP3F-(PGOM(NP2)-.5*SD(NP2))*AKAS
      D(NP2)=A(NP2)+B(NP2)+PBOM(NP2)-2.*SD(NP2)
      IF (J.NE.JVT) GO TO 520
      RM=.5*(R(NP2)+R(NP1))
      BTM=2.*(RM/R(NP1))**2
      BTMP3=(R(NP3)/RM)**2
      DTM=2.*(RM/(.75*R(NP2)+.25*R(NP1)))**2
      B(NP2)=TTMF*BTM+THLM-TMP3F*BTMP3-(PGOM(NP2)-.5*SD(NP2))*AKAS
      TT=3.*PGOM(NP2)-1.5*SD(NP2)
      IF (IKAS(J).EQ.0) TT=4.*PGOM(NP2)-2.*SD(NP2)
```

```
      B(NP2)=TTNF*DTM+TNP3F-THLM+TT
  520 T=-TNP3F*FDIFE(J)
      GO TO 2315
C ------------  EDGE FLUX SPECIFIED  ---------
 2313 A(NP2)=0.
      B(NP2)=TTNF+THLM-(PGOM(NP1)-.5*SD(NP2))*AKAS
      D(NP2)=B(NP2)+PGOM(NP2)-2.*SD(NP2)-RME*2.
      T=-RME*F(J,NP3)-AJE(J)*R(NP3)
 2315 TT=3.*F(J,NP2)+F(J,NP1)
      IF (IKAS(J).EQ.0) TT=4.*F(J,NP2)
      C(NP2)=P4OMM*TT+2.*(T+SU(NP2))
 2320 CONTINUE
C -------  MID-STREAM COEFFICIENTS  ---------
      DO 3002 I=3,NP1
      TTNF=TTPF(J)
      TPF=EN U(I)/PREF(J)
      TTPF(J)=TPF+ANLPT(I)+ABS(TPF-ANLPT(I))
      IF (J.EQ.JVT) GO TO 3015
      A(I)=TTPF(J)-THLPT(I)-PGOM(I)*AKAS
      B(I)=TTNF+THLPT(I-1)-PGOM(I-1)*AKAS
      D(I)=A(I)+B(I)+PBOM(I)-2.*SD(I)
      GO TO 2999
C ---------------
 3015 RP=.5*(R(I)+R(I+1))
      RM=.5*(R(I)+R(I-1))
      RMM=R(I-1)
      IF (I.EQ.3) RMM=.75*R(2)+.25*R(3)
      RPP=R(I+1)
      IF (I.EQ.NP1) RPP=.75*R(NP2)+.25*R(NP1)
      ATP=2.*(RP/RPP)**2
      BTM=2.*(RM/RMM)**2
      DTP=2.*(RP/R(I))**2
      DTM=2.*(RM/R(I))**2
      A(I)=TTPF(J)*ATP-THLPT(I)-PGOM(I)*AKAS
      B(I)=TTNF*BTM+THLPT(I-1)-PGOM(I-1)*AKAS
      TT=PGD4*BOMT3(I)
      IF (IKAS(J).EQ.0) TT=4.*PGD4*BOM(I)
      D(I)=TTPF(J)*DTP+TTNF*DTM+THLPT(I)-THLPT(I-1)+TT-2.*SD(I)
 2999 TT=BOMT3(I)*F(J,I)+OMB(I)*F(J,I+1)+OMB(I-1)*F(J,I-1)
      IF (IKAS(J).EQ.0) TT=4.*BOM(I)*F(J,I)
 3002 C(I)=PD4*TT+2.*SU(I)
      IF(ITEST) 3906,3907,3906
 3906 WRITE(6,3901) (A(I),I=2,NP2)
      WRITE(6,3902) (B(I),I=2,NP2)
      WRITE(6,3903) (C(I),I=2,NP2)
      WRITE(6,3904) (D(I),I=2,NP2)
 3907 CONTINUE
C -------------------------------------
      B(2)=(B(2)*F(J,1)+C(2))/D(2)
      A(2)=A(2)/D(2)
      DO 3148 I=3,NP2
      T=D(I)-B(I)*A(I-1)
      A(I)=A(I)/T
 3148 B(I)=(B(I)*B(I-1)+C(I))/T
      DO 3150 IDASH=2,NP2
      I=N+4-IDASH
 3150 F(J,I)=A(I)*F(J,I+1)+B(I)
C---------------------------  ADJUST F(J,1) AND F(J,NP3)  -------------
      GO TO (3210,3220,3230),KIN
 3210 IF(INDI(J).EQ.2) F(J,1)=FDIFI(J)+.5*(F(J,2)+F(J,3))+AJI(J)/GI(J)
      GO TO 3220
 3230 F(J,1)=.5*(F(J,2)+F(J,3))
 3220 GO TO (3310,3320,3330),KEX
 3310 IF(INDE(J).EQ.2) F(J,NP3)=FDIFE(J)+.5*(F(J,NP2)+
     1                                    F(J,NP1))-AJE(J)/GE(J)
      GO TO 3320
 3330 F(J,NP3)=.5*(F(J,NP1)+F(J,NP2))
 3320 IF(ITEST) 3322,3321,3322
 3322 WRITE(6,3323) J,(F(J,I),I=1,NP3)
 3323 FORMAT(4H F, J=,I3,1P11E11.3/(9X,11E12.3))
 3321 CONTINUE
 3060 XU=XD
      PSII=PSII-RMI*DX
      PSIE=PSIE-RME*DX
      PEI=PSIE-PSII
      IF (ISTEP.GE.IOUT) GO TO 3710
      IF (KEX.NE.2) GO TO 3700
```

```
              SUM2=SUM2-RNE*DX                                          ST     374
              GO TO 3710                                                ST     375
         3700 IF (KEX.NE.1) GO TO 3710                                  ST     376
              SUM4=SUM4-RNE*DX                                          ST     377
         3710 IF (ISTEP.GE.IEND) GO TO 3750                             ST     378
              IF (KIN.NE.2) GO TO 3740                                  ST     379
              SUM1=SUM1+RNI*DX                                          ST     380
              GO TO 3750                                                ST     381
         3740 IF (KIN.NE.1) GO TO 3750                                  ST     382
              SUM3=SUM3+RNI*DX                                          ST     383
         3750 CONTINUE                                                  ST     384
              ISTEP=ISTEP+1                                             ST     385
              RETURN                                                    ST     386
      C************************** S T R I D E 4 ************************ST     387
         4000 CONTINUE                                                  ST     388
              NO2=N/2                                                   ST     389
              NP1=N+1                                                   ST     390
              NP2=N+2                                                   ST     391
              NP3=N+3                                                   ST     392
              ON(1)=0.                                                  ST     393
              ON(NP3)=1.                                                ST     394
              ISTEP=0                                                   ST     395
              IEND=10000                                                ST     396
              IAX=10000                                                 ST     397
              IOUT=10000                                                ST     398
              DX=1.E-30                                                 ST     399
              IFIN=0                                                    ST     400
              KIN=1                                                     ST     401
              KEX=1                                                     ST     402
              RETURN                                                    ST     403
         9010 FORMAT(1H ,1P11E11.3)                                     ST     404
              END                                                       ST     405
```

```
CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

  286       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
  367       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
  371       I                 AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
```

```
SUBROUTINE WF          73/74    OPT=0 TRACE                    FTN 4.6+439        08/24/78  14.42.35        PAGE     1

            SUBROUTINE WF(J,I1,OUT1,OUT2,OUT3)                                  WF       2
            COMMON/COMA/A(43),AJE(15),AJI(15),B(43),C(43),CSALFA,D(43),        COMA     2
           1 DPDX(43),DX,EMU(43),F(15,43),FS(3,43),IAX,IEND,IFIN,INDE(15),     COMA     3
           2 INDI(15),IOUT,ISTEP,ITEST,INTRAP,JS,JSW,JV,JY,KEX,KIN,KRAD,N,     COMA     4
           3 NO2,NF,NOVEL,NP1,NP2,NP3,OM(43),OMD(43),P(43),PEI,PR(15),         COMA     5
           4 PREF(15),PSIE,PSII,R(43),RHO(43),RU(43),RME,RMI,SD(43),SU(43),    COMA     6
           5 TAUE,TAUI,U(43),XD,XU,Y(43),YE,YI,PSURL(43),RDY(43),ISOLVE(15),   COMA     7
           6 US(43),AMU(43),SUM1,SUM2,SUM3,SUM4,PDGSCH,FDIFI(15),FDIFE(15),    COMA     8
           7 GE(15),GI(15),JLOC(12),W(12),JH,JFU,JCO2,JCO,JOX,JH2O,JOH,JO,JNS, COMA     9
           8 JH2,JN,JNO,JN2,JVT,JD,JK,JT,JRT,NSP,NSPR,ABSOR,SCATR,BDM(200),    COMA    10
           9 TERM1,TERM2,ISMAX,EFU,EO2,EH2O,ERO,EPR                            COMA    11
            COMMON/COMB/AK,ALMG,EWALL,FR,H,HFU,INERT,MASSTR,MODEL,PRESS,       COMB     2
           1 UBAR,UFAC,C1,C2,CD,C2VT,AKFAC,ALFAC,ARCON1,ARCON2,PREXP1,CD75,    COMB     3
           2 PREXP2,CR1,CR2,MODER,MODCP,RATIO1,RATIO2,RATIO3,RATIO4,RATIO5,    COMB     4
           3 CX,HY,OXOLD,WFU,WCO2,WCO,WOX,WH2O,WOH,WO,WH,                      COMB     5
           4 WN2,WN,WNO,WNZ                                                    COMB     6
      C/---------- SUBROUTINE FOR PROGRAM GENMIX 4A                            WF       5
      C/------------------- D.B.SPALDING, IMPERIAL COLLEGE, 1972 -----------   WF       6
      C                                                                        WF       7
      C     EFFECTS OF PRESSURE GRADIENT AND MASS TRANSFER ARE INCLUDED        WF       8
      C     EFFECTS OF RADIUS VARIATION ARE NEGLECTED                          WF       9
      C     FOR VELOCITY,     OUT1=BP,     OUT2=T,  OUT3=TAU                   WF      10
      C     FOR F*S,          OUT1=FIDIF,  OUT2=T,  OUT3=G                     WF      11
      C                                                                        WF      12
            DATA SHALF/.04/, BPLAST/.9/                                        WF      13
            INT=1/I1                                                           WF      14
            I2=I1-1+2*INT                                                      WF      15
            I3=I1-2+4*INT                                                      WF      16
            I25=I3-INT                                                         WF      17
            IF(J) 100,100,200                                                  WF      18
      C ------------------------------------------------ VELOCITY              WF      19
        100 UREF=.5*(U(I2)+U(I3))                                              WF      20
            RHOREF=.5*RHO(I1)+.25*(RHO(I2)+RHO(I3))                            WF      21
            RUREF=RHOREF*UREF                                                  WF      22
            RREF=.5*(R(I2)+R(I3))                                              WF      23
            VREF=EMU(I1)                                                       WF      24
            YREF=YI+(YE-YI)*OM(I1)                                             WF      25
            RE=UREF*RHOREF*YREF/VREF                                           WF      26
            RRUREF=RREF*RUREF                                                  WF      27
            AM=(RMI-(RME+RMI)*OM(I1))/RRUREF                                   WF      28
            EF=YREF*DPDX(I1)/RUREF/UREF                                        WF      29
            IF(MODEL.EQ.1) GO TO 110                                           WF      30
            IF(RE.LT.132.25) GO TO 110                                         WF      31
      C--------------------------------------------------EXTENDED LOG LAW      WF      32
            ER=RE*EWALL                                                        WF      33
            NIT=0                                                              WF      34
        101 SHALF1=SHALF                                                       WF      35
            S=SHALF**2                                                         WF      36
            SLOC=S+AM+EF                                                       WF      37
            IF(SLOC.GT.0.) GO TO 104                                           WF      38
            SLOC=1.E-30                                                        WF      39
            SHALF=SQRT(ABS(AM+EF))                                             WF      40
        104 BEE=SQRT(SLOC)/AK                                                  WF      41
            ARG=ER*(SHALF+(AM/(1.+BEE)+.5*EF)/SHALF)                           WF      42
            IF(ARG.GT.11.5*EWALL) GO TO 106                                    WF      43
            GO TO 110                                                          WF      44
        106 SHALF=AK/ALOG(ARG)                                                 WF      45
            IF(ABS(SHALF-SHALF1).LT..0001.OR.NIT.GT.10) GO TO 102              WF      46
            NIT=NIT+1                                                          WF      47
            GO TO 101                                                          WF      48
        102 S=SHALF**2                                                         WF      49
            SAV=.5*(SHALF**2+SLOC)                                             WF      50
            OUT1=1./(1.+BEE)                                                   WF      51
            EM U(I25)=.25*RHOREF*RREF*ABS(U(I3)-U(I2))*(AK/OUT1)**2            WF      52
            GO TO 103                                                          WF      53
      C ---------------------------------------------- LAMINAR FLOW            WF      54
        110 AMRE=AM*RE                                                         WF      55
            FRE=EF*RE                                                          WF      56
            IF(ABS(AMRE).LT..01) GO TO 111                                     WF      57
            AMRE=AMAX1(-60.,AMIN1(60.,AMRE))                                   WF      58
            EXPMRE=EXP(AMRE)                                                   WF      59
            STORE=EXPMRE-1.-AMRE                                               WF      60
            AMRESQ=AMRE*AMRE                                                   WF      61
            SRE=AMRE*(1.-STORE*FRE/AMRESQ)/(EXPMRE-1.)                         WF      62
            OUT1=SRE*STORE/AMRESQ+FRE*(STORE-.5*AMRESQ)/(AMRESQ*AMRE)          WF      63
            GO TO 112                                                          WF      64
        111 SRE=(2.-FRE*(1.+AMRE/3.))/(2.+AMRE)                                WF      65
```

```
   49 A(K)=BLANK                                                    PL    79
   40 CONTINUE                                                      PL    80
      DO 50 I=1,11                                                  PL    81
   50 A(I)=.1*FLOAT(I-1)                                            PL    82
      WRITE(6,104) (A(I),I=1,11)                                    PL    83
      RETURN                                                        PL    84
  100 FORMAT(11H Y-ANES ARE,5X,10(1X,A6,A4))                        PL    85
  101 FORMAT(1H0,2X,11F10.1)                                        PL    86
  102 FORMAT(15H MAXIMUM VALUES,1P10E11.3)                          PL    87
  103 FORMAT(11H0X-AXIS IS ,A8,17H ,MAXIMUM VALUE =,1PE10.3)        PL    88
  104 FORMAT (3X,11F10.1)                                           PL    89
  105 FORMAT(2H I,F6.2,3X,101A1,F6.2)                               PL    90
  106 FORMAT(7H SYMBOL,11X,10(1X,A10))                              PL    91
      END                                                           PL    92
```

APPENDIX G

LISTING OF FUEL INSTRUCTION MODEL


```
      PROGRAM INJECTI (INPUT,OUTPUT,TAPE60=INPUT,TAPE61=OUTPUT)
C
C     PROGRAM TO CALCULATE TRAJECTORIES FOR SIMPLEX OR DUAL ORIFICE
C     INJECTORS
C     CHANGES AND ADDITIONS MADE 3/2/71 TO INTERFACE SR EVAP
C     CHANGES AND ADDITIONS MADE 7/29/71  FOR GOSMAN COMPATIBILITY
C     CHANGES REFLECT PLANS FOR THIS ROUTINE TO BECOME PART OF GOSMAN
C
C     OUTPUT OF ROUTINE IS LOCATION OF E= .1,.2,.3,.....9 FOR EACH OF 5
C             DROPLET GROUPS
      COMMON /OUTPT/ X1E(5,10),X2E(5,10)
      COMMON /KTMA/ X1(21),X2(21),G1(21,21),G2(21,21),RO(21,21),T(21,21)
     1,IN,JN,P(21),FEVAP(21,21)
CCCCCC
      DIMENSION DRD(102,5), EVP(102,5), TTF(102,5), VEF(102,5)
C
      COMMON /TABLES/ T1(7),VISAIR(7),T2(2,4),SGFUEL(2,4),T3(12,4),VISFU
     1L(12,4),NTAB1,NTAB2,NTAB3,NFUELS,DIASMD(5,2),NDIASM,T5(10),SRFTNS(
     210,4),NTAB5S,NTAB5T,SGTAB5(4)
      DIMENSION FLOWS(5), DELPS(5), X(102,5), Y(102,5), NNN(5), DIA(5),
     1LABELS(6), DUPDUP(4)
      DIMENSION LABELF(4)
      COMMON /TRAJ/ VFUEL,TFUEL?,TFUELF,SD,FMU,RHOFUL,PS,PT,TS,TT,RHOAIR
     1,AMU,G,VAIRST,SMD
      COMMON /INPUT/ KFUEL,DEQ,GAP,PPH,TITLE(8)
      COMMON /QEVAP/ DUMMY(20),D(5),TF(5),VF(5),VREL(5),RN(5),CD(5),DRAG
     1(5),FN(5),CP(5),DELQ(5),SG(5),FRHO(5),DELTF(5),TIMS(5),FMASS(5),AL
     2PHA(5),DELV(5),E(5),DX,W(5),VFSAVE(5),TFSAVE(5),DSAVE(5),ESAVE(5),
     3DSTART(5),SGSG60(5),SG60(5),DELM(5),OPTION,VAIRH,VAIRV,SINT,COST,D
     4UM1,DUM2,WST(5),EW(5)
C
      DATA LABELF/10HSHELLDYN 4,10HJP5---JP3 ,10HJET A-1   ,3HJP4/
      DATA KPLOT/0/
      DATA LABELS/8H 0 -  20,8H20 -  40,8H40 -  60,8H60 -  80,8H80 - 100
     1,10H / VOLUME /
C
C     DIASMD IS TABLE OF DIA/SMD (DMLS) VALUES FOR 1= WITHOUT AIR ASSIST
C                                                 2= WITH AIR ASSIST
C     T1, VISAIR IS TABLE OF TEMPERATURE (F) VS.
C                         VISCOSITY OF AIR (LB/SEC/FT)
C     T2, SGFUEL IS TABLE OF TEMPERATURE (F) VS.
C                         SPECIFIC GRAVITY (DMLS)
C     FOR 4 FUELS-- SHELLDYNE 4, JP5---JP3, JET A-1, JP4
C     T3, VISFUL IS TABLE OF TEMPERATURE (F) VS.
C                         VISCOSITY OF FUEL (CENTISTOKES)
C     FOR 4 FUELS LISTED ABOVE
      DATA DIASMD/.623,.932,1.18,1.45,1.90,.623,.932,1.18,1.45,1.90/
      DATA NTAB1,NTAB2,NTAB3,NFUELS/7,2,12,4/,NDIASM/5/
      DATA (T1(I),I=1,7)/40.,540.,1040.,1540.,2040.,2540.,3040./,(VISAIR
     1(I),I=1,7)/1.17E-5,1.89E-5,2.50E-5,3.01E-5,3.48E-5,3.90E-5,4.29E-5
     2/
      DATA T2/24.,300.,0.,220.,36.,260.,55.,200./,SGFUEL/1.1,.975,.85,.7
     1625,.825,.7375,.775,.7125/
      DATA T3/-50.,0.,40.,60.,80.,100.,150.,200.,250.,300.,350.,400.,-50
     1.,0.,40.,60.,80.,100.,125.,150.,175.,200.,225.,250.,-50.,0.,40.,60
     2.,80.,100.,125.,150.,175.,200.,225.,250.,-50.,0.,40.,60.,80.,100.,
     3125.,150.,175.,200.,225.,250./,VISFUL/3000.,210.,55.,32.,20.,14.,6
     4.5,3.6,2.1,1.35,.9,.64,23.,6.2,3.75,2.5,2.,1.65,1.35,1.15,.98,.84,
     5.75,.67,19.,5.4,2.9,2.3,1.55,1.55,1.3,1.08,.92,.81,.72,.64,4.7,2.1
     65,1.43,1.23,1.04,.93,.79,.69,.61,.55,.49,.44/
      DATA T5/50.,100.,150.,200.,250.,300.,350.,400.,450.,500./
      DATA SGTAB5/.72,.76,.80,.84/
      DATA NTAB5T,NTAB5S,NTAB8F/10,4,7/
      DATA SRFTNS/21.,18.2,15.5,13.,10.6,8.2,5.9,3.9,2.0,.2,23.1,20.5,18
     1.0,15.6,13.4,11.1,9.0,7.0,5.1,3.3,23.9,21.8,19.6,17.5,15.4,13.4,11
     2.4,9.5,7.7,6.,24.9,22.9,21.0,19.1,17.3,15.5,13.8,12.1,10.4,8.8/
      CALL PLOTS (0,0,0)
C     INPUT DATA
      XP=2.0
      YO=2.0
      YOT=0.0
      ICASE=0
   10 READ (60,530) TITLE
      IF (EOF(60)) 20,30
   20 CALL PLOT (0.,0.,999)
      CALL EXIT
   30 WRITE (61,540) TITLE
```

```
      ICASE=ICASE+1
      DO 40 I=1,500
      X(I)=0.
   40 Y(I)=0.
      XMAX=10.
      YMAX=10.
      XSTART=0.
      YSTART=0.
CCCCCC
      READ (60,550) KORIF,KAIRAS,FN1,FN2,CONEAN,AREASH,DORF1,DORF2
      IF (KORIF.EQ.1) WRITE (61,560) FN1,CONEAN,DORF1
      IF (KORIF.EQ.2) WRITE (61,570) FN1,FN2,CONEAN,DORF1,DORF2
      IF (KORIF.EQ.3) WRITE (61,1000) CONEAN
 1000 FORMAT (1X,*AIRBLAST ATOMIZER, CONE ANGLE =*,F8.1)
      IF (KORIF.EQ.4) WRITE (61,1105) CONEAN
 1105 FORMAT (1X,*PNEUMATIC IMPACT ATOMIZER, CONE ANGLE =*,F8.1)
      IF (KAIRAS.EQ.1) WRITE (61,593)
      IF (KAIRAS.EQ.2) WRITE (61,590) AREASH
      IF (KORIF.NE.2) GO TO 50
      READ (60,600) FLOWS
      WRITE (61,630) FLOWS
      READ (60,500) DELPS
      WRITE (61,640) DELPS
   50 IF (KORIF.NE.3.AND.KORIF.NE.4) GO TO 1010
      READ (60,600) DFILM,WNOZ,AFLO,T3S
      WRITE (61,1015) DFILM,WNOZ,AFLO,T3S
 1015 FORMAT (1X,*FILM DIA, NOZZLE AIRFLOW, FLOW AREA,T3S,*,
     1 4F10.4)
 1010 CONTINUE
CCCCCC
      READ (60,610) KFUEL,IOPT,TFUEL,PP4,DELP,DELPS4,TS4
      WRITE (61,620) KFUEL,IOPT,TFUEL,PP4,DELP,DELPS4,TS4
      IF (IOPT.NE.1) GO TO 60
CCCCCC
      READ (60,500) TAMB,VAIR,PS,XMAX,YMAX
      WRITE (61,660) TAMB,VAIR,PS
      GO TO 70
   60 CONTINUE
C     XSTART, YSTART ARE INPUT IN INCHES
CCCCCC
      READ (60,600) XSTART,YSTART,PS,XMAX,YMAX
      WRITE (61,650) XSTART,YSTART,PS,XMAX,YMAX
      XSTART=XSTART/12.
      YSTART=YSTART/12.
      XMAX=XMAX/12.
      YMAX=YMAX/12.
   70 CONTINUE
      VAA=0.
      WAIR=0
      IF (KAIRAS.EQ.1) GO TO 80
      PR=(PS+DELPSH)/PS
      FMA2=5.*(PR**.2857-1.)
      IF (FMA2.GT.1.) FMA2=1.
      TSA=TSH/(1.+.2*FMA2)
      VAA=49.02*SQRT(TSA*FMA2)
      RHOAIR=2.6995*PS/TSA
      PPP=(1.+.2*FMA2)**3.5
      PSP=(PS+DELPSH)/PPP
      WAIR=AREASH*VAA*2.6995*PSP/TSA/144.*3600.
      WRITE (61,810) WAIR,VAA
   80 TFUELR=TFUEL
      TFUEL=TFUEL-459.69
C     SPECIFIC GRAVITY (EMLS) FOR FUEL
      SGF=TAB(TFUEL,T2(1,KFUEL),SGFUEL(1,KFUEL),NTAB2)
      SG60F=TAB(60.,T2(1,KFUEL),SGFUEL(1,KFUEL),NTAB2)
      DO 90 I=1,NTAB5S
   90 DUMDUM(I)=TAB(TFUEL,T5,SRFTNS(1,I),NTAB5T)
      TAU=TAB(SG60F,SGTAB5,DUMDUM,NTAB5S)
C     DENSITY OF FUEL
      RHOFUL=62.428*SGF
C     VISCOSITY OF FUEL (CENTISTOKES)
      FMU=TAB(TFUEL,T3(1,KFUEL),VISFUL(1,KFUEL),NTAB3)
      WRITE (61,740) SGF,FMU
      IF (KORIF.EQ.3.OR.KORIF.EQ.4) GO TO 1020
      CONX=COS(CONEAN/57.29578*.5)*SQRT(RHOFUL)
      SLM1=3.359*FN1/DORF1/CONX
      SLM2=0.
```

```
      IF (KORIF.NE.1) SLP2=3.353*FM2/[illegible]
      SLP=SLP1+SLP2
      WRITE (61,800) SLP1,SLP2
C     CONSTANTS FOR CALCULATIONS
 1020 CON1=.764/SGF
      CON2=PPM**.295
      CON3=(FMU/1.5)**.3
      CON4=9266./RHOFUL
CCCCCC
      ELIP=.96
      SI=.21
      S=SI/12.
      DX=S
      CON9=39.37E-6/12.
C
      IF (ICASE.GT.1.AND.ICPT.EQ.2) GO TO 98
      IM=2
      JM=2
      VAIRM1=VAIR
      VAIRV1=0.
      TS1=TAMB
      VAIRM=VAIRM1
      VAIRV=VAIRV1
      TS=TS1
      X1(1)=0.
      X2(1)=0.
      X1(IM)=XMAX/12.
      X2(JM)=YMAX/12.
      IF (ICPT.EQ.1) GO TO 110
      READ (60,900) IM,JM
  900 FORMAT (5(I2,8X))
      READ (60,910) (X1(I),I=1,IM)
  910 FORMAT (8E10.4)
      READ (60,910) (X2(I),I=1,JM)
      DO 920 J=1,JM
  920 READ (60,910) (G1(I,J),I=1,IM)
      DO 930 J=1,JM
  930 READ (60,910) (G2(I,J),I=1,IM)
      DO 940 J=1,JM
  940 READ (60,910) (T(I,J),I=1,IM)
      DO 950 J=1,JM
      Y(J)=X2(J)
      DO 950 I=1,IM
      RHO=PS*144./53.3/T(I,J)
      G1(I,J)=G1(I,J)*RHO
      G2(I,J)=G2(I,J)*RHO
  950 RC(I,J)=RHO
   98 DO 100 I=1,441
  100 FEVAP(I)=0.
  110 CONTINUE
C     CALCULATIONS BEGIN * * * * * * * * *
      DELP1=(PPM*CON1/FM1)**2
      GO TO (120,1030,1035,1035), KORIF
 1030 IF (DELP1.GE.DELPS(1)) GO TO 150
      WRITE (61,670)
      KORIF=1
      GO TO 130
  120 IF (DELP1.NE.0.) GO TO 130
      DELP1=DELP
      PPM=FM1*SQRT(DELP1/CON1)
      CON2=PPM**.295
  130 VFUEL=SQRT(CON4*DELP1)
      IF (KAIRAS.EQ.2) GO TO 140
      SMD=225.*CON2*CON3/DELP1**.354
      GO TO 150
  140 GMR=WAIR/PPM
      VR=VFUEL/VAB
      VEP=.43*GMR**.1*VAB*SQRT(.5+VR**2-VR)
      SMD=196.*SQRT(TAU*SL*/[illegible])**.[illegible]/VEP
  150 DELPEO=DELP1
      DELP2=0.
      DELPVM=0.
      PPM1=PPM
      PPM2=0.
      GO TO 240
  160 KPASS=0
      KCUNT=0
```

```
      DO 220 I=1,5
      DELPWW=DELPS(I)
  170 PPW2=TAB(DELPWW,DELPS,PLOWS,5)
      DELP2=(PPW2*CC*2/FW2)**2
      PP1=PPF-PPW2
      DELP1=(PP1*CC*1/FP1)**2
      DELPWS=DELP1-DELP2
      ERROR=DELPWW-DELPWS
      IF (ABS(ERROR).LE..1) GO TO 220
      IF (I.EQ.1) GO TO 200
      IF (ERROR*ERRORO.LT.0.) GO TO 180
      IF (CROSS.EQ.1) GO TO 210
      DELPWO=DELPWW
      ERRORO=ERROR
      GO TO 190
  180 IF (CROSS.NE.0) GO TO 190
C     ROOT IS BETWEEN DELPS(I-1) AND DELPS(I)
      CROSS=1
      DELTA=DELPWW-DELPWO
  190 DELTA=DELTA*.5
      DELPWW=DELPWT+DELTA
      COUNT=COUNT+1
      IF (COUNT.LT.50) GO TO 170
      WRITE (61,600) DELPWO,DELPWW
      CALL EXIT
  200 ERRORO=ERROR
      DELPWO=DELPWW
  210 CONTINUE
      WRITE (61,610)
      CALL EXIT
C     CONVERGENCE
  220 DELPF=[illegible]
      VFUEL=SQRT(C2*4*DELPFS)
      IF (WATRAS.EQ.2) GO TO 230
      TM=330.*CD*2*(FW/2.5)**.3/DELPF**.256
      GO TO 240
  230 [illegible]
      [illegible]
      [illegible]
      [illegible]
      GO TO 240
C     ------------- AIRBLAST AND PNEUMATIC IMPACT -------------
C     DATA FROM - "THE INFLUENCE OF AIR AND LIQUID PROPERTIES IN
C                 AIRBLAST ATOMIZATION", A.A. RIZKALLA AND A.H. LEFEBVRE,
C                 ASME FLUID MECHANICS OF COMBUSTION (1974)
C
 1035 [illegible]
      [illegible]=2.54
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
  240 CONTINUE
C     [illegible]
C     [illegible]
      THETA1=THETA/57.29578
      STHETA=SIN(THETA1)
      CTHETA=COS(THETA1)
      [illegible]
      IF ([illegible].EQ.1) CALL ATOMSS ([illegible])
      RETURN
```

```
      WRITE (61,710) DELP1,PPH1,DELP2,PPH2,DELPVN,VFUEL,SMD
      WRITE (61,6201) GMM,VEP
      DO 400 I=1,5
C     DIA IS IN MICRONS
      DIA(I)=DIASMD(I,KAIRAS)*SMD
C     D IS IN FEET
      D(I)=DIA(I)*CON9
      E(I)=0.
      EW(I)=0.
      W(I)=D(I)**3*RHOFUL*3.14159265/6./1.5
      WST(I)=W(I)
      VF(I)=VFUEL
      TF(I)=TFUEL*
      INTER=1
      KKK=1
C **  THETA= THETA1
      SINT=SINT1
      COST=COST1
      X(1,I)=XSTART
      Y(1,I)=YSTART
      K1=0
      EW1=EW(I)
      IF (IOPT.EQ.2) CALL FEVAPC (XSTART,YSTART,K1,EW1,EW(I))
CCCCCC
      DP0(1,I)=D(I)/CON9
      EVP(1,I)=0.
      TTF(1,I)=TFUEL*
      VFF(1,I)=VFUEL
CCCCCC
      VAIRH=VAIRH1
      VAIRV=VAIRV1
      TS=TS1
      KOVER=1
      KOUNT=2
      XOLD=XSTART
      YOLD=YSTART
      KOLD=1
  250 IF (KOLD.LT.6) GO TO 260
      KOLD=1
      KOUNT=KOUNT+1
      IF (KOUNT.GT.100) GO TO 350
CCCCCC
  260 IF (E(I).LT.ELIM) CALL EVAP (INTER,I)
      IF (INTER.LT.0) GO TO 399
      INTER=2
C     X, Y IN FEET
      X(KOUNT,I)=XOLD+S*COST
      Y(KOUNT,I)=YOLD-S*SINT
      W(I)=W(I)-DELW(I)
      EW(I)=1.-W(I)/WST(I)
      IF (IOPT.EQ.2) CALL FEVAPC (X(KOUNT,I),Y(KOUNT,I),K1,EW1,EW(I))
CCCCCC
      DPO(KOUNT,I)=D(I)/CON9
      EVP(KOUNT,I)=E(I)*100.
      IF (E(I).LT..001) EVP(KOUNT,I)=0.
      TTF(KOUNT,I)=TF(I)
      VFF(KOUNT,I)=VF(I)
CCCCCC
C     CHECK IF THIS INTERVAL CROSSED EVAP. STORE POINT
      *****
CCCCCC
      DO 270 L=K,10
      KK=L
      EP=FLOAT(L)*.1
      IF (L.EQ.10) EP=.95
      IF (ESAVE(I).GE.EP.OR.E(I).LT.EP) GO TO 280
C     INTERPOLATE FOR (X1,X2) IN FEET
      DUM=0.
      TEMP=E(I)-ESAVE(I)
      IF (TEMP.NE.0.) DUM=(EP-ESAVE(I))/TEMP
      X1E(I,L)=XOLD+DUM*(X(KOUNT,I)-XOLD)
      X2E(I,L)=YOLD+DUM*(Y(KOUNT,I)-YOLD)
      XINCH=X1E(I,L)*12.
      YINCH=X2E(I,L)*12.
  270 WRITE (61,730) I,EP,XINCH,YINCH
      GO TO 391
C     CHECK IF HAVE HIT A PROBE
```

```
  280 IF (X(KOUNT,I).GE.X1(1)) GO TO 290
      DUM=4HLEFT
      GO TO 320
  290 IF (X(KOUNT,I).LE.X1(IN)) GO TO 300
      DUM=5HRIGHT
      GO TO 320
  300 IF (Y(KOUNT,I).GE.Y2(1)) GO TO 310
      DUM=6HBOTTOM
      GO TO 320
  310 IF (Y(KOUNT,I).LE.Y2(JN)) GO TO 350
      DUM=3HTOP
  320 WRITE (61,780) I,DUM
  330 DO 340 L=KKK,10
      X1E(I,L)=X(KOUNT,I)
  340 X2E(I,L)=Y(KOUNT,I)
      GO TO 390
  350 IF (INTER.LT.0) GO TO 330
C **  THETA= ATAN2(DUM1,DUM2)
      SINT=DUM1/VF(I)
      COST=DUM2/VF(I)
      XOLD=X(KOUNT,I)
      YOLD=Y(KOUNT,I)
      KOLD=KOLD+1
      IF (IOPT.EQ.2) CALL AIRPRP (X(KOUNT,I),Y(KOUNT,I),VAIRH,VAIRV,TS)
      GO TO 250
  360 KOVER=KOVER+1
      IF (KOVER.LT.10) GO TO 370
      WRITE (61,760) I
      KOUNT=KOUNT-1
      GO TO 330
C     COMPRESS 100 PTS INTO 50 AND CONTINUE
  370 DO 380 J=4,100,2
      K=J/2
CCCCCC
      DRD(K,I)=DRD(J,I)
      EVP(K,I)=EVP(J,I)
      TTF(K,I)=TTF(J,I)
      VFF(K,I)=VFF(J,I)
CCCCCC
      X(K,I)=X(J,I)
  380 Y(K,I)=Y(J,I)
      KOUNT=51
      GO TO 250
  391 WRITE (61,750) I
  390 NNN(I)=KOUNT
      IF (MAXK.LT.KOUNT) MAXK=KOUNT
      K1=-1
      IF (IOPT.EQ.2) CALL FEVAPC (X(KOUNT,I),Y(KOUNT,I),K1,EM1,EM(I))
  400 CONTINUE
      IF (IOPT.EQ.1) GO TO 410
      IEND=0
      WRITE (61,770)
  401 ISTR=IEND+1
      IEND=ISTR+11
      IF (IEND.GT.IN) IEND=IN
      DO 405 JJ=1,JN
      J=JN-JJ+1
  405 WRITE (61,406) (FEVAP(I,J),I=ISTR,IEND)
      WRITE (61,403)
  403 FORMAT (1H0)
  406 FORMAT (12E11.3)
      IF (IEND.LT.IN) GO TO 401
  410 WRITE (61,750) (I,TF(I),VF(I),D(I),F(I),I=1,5)
      WRITE (61,720) (LABELS(I),LABELS(6),I=1,5),(DTA(I),I=1,5)
      DO 430 I=1,5
      N=NNN(I)+1
      IF (N.GT.MAXK) GO TO 430
      DO 420 J=N,MAXK
      DRD(J,I)=0.
      TTF(J,I)=0.
      VFF(J,I)=0.
      EVP(J,I)=0.
      X(J,I)=0.
  420 Y(J,I)=0.
  430 CONTINUE
      DO 450 J=1,MAXK
C     CONVERT TO INCHES FOR PLOTTING AND PRINTING
```

```
      DO 440 I=1,5
      X(J,I)=X(J,I)*12.
  440 Y(J,I)=Y(J,I)*12.
CCCCCC
      WRITE (61,730) (X(J,I),Y(J,I),I=1,5),(DP(J,I),TTF(J,I),VEF(J,I),E
     1VP(J,I),I=1,5)
  450 CONTINUE
C     PLOTTING
      RXMAX=0.
      RXMIN=100000.
      RYMAX=0.
      RYMIN=100000.
      DO 445 I=1,5
      N=NNN(I)
      DO 445 J=1,N
      RXMAX=AMAX1(RXMAX,X(J,I))
      RXMIN=AMIN1(RXMIN,X(J,I))
      RYMAX=AMAX1(RYMAX,Y(J,I))
  445 RYMIN=AMIN1(RYMIN,Y(J,I))
      CALL PLOT (XO,YO,-3)
      XO=0.0
      YO=8.5
      YOT=YOT+YO
      IF (YOT.LT.20.) GO TO 460
      XO=11.
      YO=-17.
      YOT=0.0
  460 CALL SCALES (RYMAX,RYMIN,5.0,STEPY,STARTY)
      CALL SCALES (RXMAX,RXMIN,9.0,STEPX,STARTX)
      CALL AXIS (0.,0.,1HX,-1,9.0,0.,STARTX,STEPX)
      CALL AXIS (0.,0.,1HY,1,5.0,90.,STARTY,STEPY)
CCCCCC
      YL=6.0
      DO 470 I=1,5
      N=NNN(I)
      X(N+1,I)=STARTX
      Y(N+1,I)=STARTY
      X(N+2,I)=STEPX
      Y(N+2,I)=STEPY
      CALL LINE (X(1,I),Y(1,I),N,1,10,I)
CCCCCC
      XL=4.5
      YL2=YL+.05
      CALL SYMBOL (XL,YL2,0.1,I,0.,-1)
      XL=XL+.2
      CALL SYMBOL (XL,YL,.10,LABELS(I),0.,9)
      XL=XL+.80
      CALL SYMBOL (XL,YL,.10,44,0.,-1)
      XL=XL+.2
      CALL SYMBOL (XL,YL,0.1,3HVOL,0.,3)
CCCCCC
      XL=XL+0.5
      CALL NUMBER (XL,YL,.1,DIA(I),0.,2)
      XL=XL+0.7
      CALL SYMBOL (XL,YL,.1,7HMICRONS,0.,7)
CCCCCC
      XL=XL+1.4
      CALL NUMBER (XL,YL,0.1,F(I),0.0,2)
      YL=YL+.2
  470 CONTINUE
      CALL SYMBOL (4.8,7.1,0.1,7HDROPLET,0.0,7)
      CALL SYMBOL (6.7,7.1,0.1,4HSIZE,0.0,4)
      CALL SYMBOL (8.1,7.1,0.1,13HFRAC.EVAP.,0.0,13)
CCCCCC
      YL=7.5
      CALL SYMBOL (0,0,YL,.15,TITLE,0.,80)
      YL=YL-0.5
      CALL SYMBOL (1.0,YL,.1,21HINJECTOR TRAJECTORIES,0.,21)
      YL=YL-0.2
      IF (NORIF.NE.1) GO TO 1040
      CALL SYMBOL (0.5,YL,0.1,7HSIMPLEX,0.,7)
      GO TO 490
 1040 IF (NORIF.NE.2) GO TO 1050
  480 CALL SYMBOL (0.5,YL,0.1,12HDUAL ORIFICE,0.,7)
      GO TO 490
 1050 IF (NORIF.NE.3) GO TO 1055
      CALL SYMBOL (0.5,YL,0.1,8HAIRBLAST,0.,8)
```

```
      GO TO 490
 1055 IF (KORIF.NE.4) GO TO 490
      CALL SYMBOL (0.5,YL,0.1,18HPNEUMATIC IMPACT,0.,16)
  490 IF (KAIRAS.EQ.1) GO TO 500
      CALL SYMBOL (2.5,YL,0.1,4HWITH,0.,4)
      GO TO 510
  500 CALL SYMBOL (2.5,YL,0.1,7HWITHOUT,0.,7)
  510 CALL SYMBOL (3.2,YL,0.1,10HAIR ASSIST,0.,10)
      YL=YL-0.2
      CALL SYMBOL (0.5,YL,0.1,11HCONE ANGLE=,0.,11)
      CALL NUMBER (1.7,YL,0.1,CMEAN,0.,2)
      YL=YL-0.2
      CALL SYMBOL (0.5,YL,0.1,5HFUEL=,0.,5)
      CALL SYMBOL (1.1,YL,0.1,[illegible],0.,10)
      CALL SYMBOL (2.5,YL,0.1,7HFUEL T=,0.,7)
      CALL NUMBER (3.2,YL,0.1,TFUEL,0.,1)
CCCCCC
      YL=YL-0.2
      CALL SYMBOL (0.5,YL,0.1,4HSMD=,0.,4)
      CALL NUMBER (1.0,YL,0.1,SMD,0.,2)
      CALL SYMBOL (1.8,YL,0.1,7HMICRONS,0.,7)
CCCCCC
      YL=YL-0.4
      CALL SYMBOL (0.5,YL,0.1,28HFLOW NUMBER  PPH     DELTA P,0.,28)
      YL=YL-.15
      CALL NUMBER (0.5,YL,.1,FN1,0.,3)
      CALL NUMBER (1.7,YL,.1,PPH1,0.,2)
      CALL NUMBER (2.3,YL,.1,DELP1,0.,2)
      IF (KORIF.NE.2) GO TO 579
      YL=YL-.15
      CALL NUMBER (0.5,YL,.1,FN2,0.,5)
      CALL NUMBER (1.7,YL,.1,PPH2,0.,2)
      CALL NUMBER (2.3,YL,.1,DELP2,0.,2)
      YL=YL-0.2
      CALL SYMBOL (0.5,YL,.1,12HFLOW DIVIDER,0.,12)
      YL=YL-0.15
      CALL SYMBOL (1.,YL,.1,14HCRACK DELTA P=,0.,14)
      CALL NUMBER (2.4,YL,.1,DELPS(1),0.,2)
      YL=YL-.15
      CALL SYMBOL (1.,YL,.1,14HVALVE DELTA P=,0.,14)
      CALL NUMBER (2.4,YL,.1,DELPV,0.,2)
  520 CONTINUE
      GO TO 10
CCCCCC
CCCCCC
C
  530 FORMAT (8A10)
  540 FORMAT (1H1,8A10/)
  550 FORMAT (2I5,6F10.0)
  560 FORMAT (1X,32HSIMPLEX ATOMIZER, FLOW NUMBER = ,F10.5,14H CONE ANGL
     1E= F10.5,15H ORIF DIA=F6.3)
  570 FORMAT (1X,34HDUAL ORIFICE ATOMIZER, PRIM FLOW NO = ,F10.5,15H SEC
     1 FLOW NO = F10.5,14H CONE ANGLE = F10.5/15H PRIM ORIF DIA=F6.3,14H
     2 SEC ORIF DIA=F6.3)
  580 FORMAT (1X,18HWITHOUT AIR ASSIST)
  590 FORMAT (1X,32HWITH AIR ASSIST,  SHROUD AREA = ,F10.5,6H SQ IN)
  600 FORMAT (8F10.0)
  610 FORMAT (2I5,5F10.0)
  620 FORMAT (2I,39HFUEL ICPT TEVEL PPH DELP DELPSH TSH = ,2I5,5F10.5)
  630 FORMAT (1X,17HSEC FLOW SCHED = ,5F10.5)
  640 FORMAT (1X,17HSEC PRES SCHED = ,5F10.5)
  650 FORMAT (1X,24HARBITRARY FLOW OPTION, V START, V START, P GAS, R MA
     1X, T MAX =,5F10.5)
  660 FORMAT (1X,43HUNIFORM FLOW OPTION, T END, VAIR, P AMB = ,3F10.5)
  670 FORMAT (43HDUAL ORIFICE TO ACTING AS SIMPLEX ATOMIZER)
  680 FORMAT (22H0ITERATIONS, DELPV=F12.6,4X,7HDFLOWN=F12.6)
  690 FORMAT (39HCNT SOLUTION WITHIN VALVE TABLE VALUES)
  700 FORMAT (62HITERATION REACHED MAX. OF 500 FOR DROPLET,I5,2IH, CALC
     1ULATION STOPPED)
  710 FORMAT (/13HODELTA P (1)=,F10.2,5X,8HPPH (1)=F10.2/13H DELTA P (2)
     1=,F10.2,5X,8HPPH (2)=,F10.2/[illegible] F10.2,7X,6HFUEL=F10.
     22/6H SPD= ,F10.2)
  720 FORMAT [illegible]
     1[illegible]
     2[illegible]
  730 FORMAT (2X,5(F10.2,F11.2,5X)/[illegible])
  740 FORMAT [illegible] F12.6,12H CENTISTOKE
```

PROGRAM INJECT1   73/74   OPT=0 TRACE   FTN 4.6+439   08/24/78 14.29.13   PAGE   9

```
     15)
750  FORMAT (8H DROPLET,I3,15H HAS EVAPORATED)
760  FORMAT (26H0LAST DROPLET CONDITIONS--/6X,4HDROP,5X,2HTF,13X,2HVF,1
     14X,1HD,14X,1HE/5(5X,I5,4E15.5/1/)
770  FORMAT (7H0FEVAP=/2(1(1H0,7F12.6/2(1X,7F12.6/)))
780  FORMAT (13H0***** DROPLET,I3,3H HAS HIT ,A7,8H BOUNDARY)
790  FORMAT (8H0DROPLET,I3,3H F=F6.2,5X,4H X1= X2=2F9.5,3H IN)
800  FORMAT (26H0FUEL SHEET THICK.. =F9.1,7H. SEC =F9.1,8H MICRONS
     1)
810  FORMAT (17H0ASSIST AIR FLOW=F9.3,6H LB/HR,10H VELOCITY=F7.1,4H FPS
     1)
820  FORMAT (21H0AIR/FUEL MASS RATIO=F12.3,19H EFF. AIR VELOCITY=F10.1)
     END
```

```
      SUBROUTINE FEVAPC (X,Y,W1,FW1,FW)
      COMMON /XYMN/ X1(21),X2(21),S1(21,21),S2(21,21),P3(21,21),T(21,21)
     1,IM,JM,R(21),FEVAP(21,21)
      COMMON /INPUT/ WFUEL,DEQ,GAP,RPM
C     CALC. AND STORE FUEL EVAPORATION RATE FOR SYSMAN PROGRAM
C
      IF (W1.LT.0) GO TO 50
C     DETERMINE WHICH ELEMENT VOLUME
      JM1=JM-1
      DO 10 JJ=2,JM1
      S1=(X2(JJ)+X2(JJ-1))*0.5
      IF (JJ.EQ.2) S1=X2(1)
      S2=(X2(JJ)+X2(JJ+1))*0.5
      IF (JJ.EQ.JM1) S2=X2(JM)
      IF (Y.LT.S1.OR.Y.GE.S2) GO TO 10
      J=JJ
      GO TO 20
   10 CONTINUE
      GO TO 40
   20 IM1=IM-1
      DO 30 II=2,IM1
      S1=(X1(II)+X1(II-1))*0.5
      IF (II.EQ.2) S1=X1(1)
      S2=(X1(II)+X1(II+1))*0.5
      IF (II.EQ.IM1) S2=X1(IM)
      IF (X.LT.S1.OR.X.GE.S2) GO TO 30
      I=II
      GO TO 80
   30 CONTINUE
C     NOT IN A VOLUME
   40 IF (W1.EQ.0) RETURN
      IF (ISAVE.EQ.0) RETURN
      I=0
C     CALC. FEVAP(I,J) FOR ISAVE, JSAVE
   50 IF (ISAVE.EQ.0) RETURN
      VOL=(X1(ISAVE+1)-X1(ISAVE-1))*(X2(JSAVE+1)-X2(JSAVE-1))*0.25*R(JSAV
     1E)
      IF (R(JSAVE).NE.1..OR.R(JSAVE+1).NE.1.) VOL=VOL*6.2832*R
      DFW=FW-FW1
      FEVAP(ISAVE,JSAVE)=FEVAP(ISAVE,JSAVE)+DFW*RPM/1000./VOL
      FW1=FW
      IF (I.NE.0) GO TO 60
      ISAVE=0
      W1=0
      RETURN
   60 ISAVE=I
      JSAVE=J
   70 RETURN
   80 IF (W1.NE.0) GO TO 90
      W1=1
      GO TO 60
   90 IF (I.EQ.ISAVE.AND.J.EQ.JSAVE) GO TO 70
      GO TO 50
      END
```

SUBROUTINE AIRPRP 73/74 OPT=1 TRACE FTN 4.6+439 PAGE 1

```
      SUBROUTINE AIRPRP (X,Y,VAIRH,VAIRV,TS)
      COMMON /PRIME/ X1(21),X2(21),G1(21,21),G2(21,21),P(21,21),T(21,21)
     1,IM,JM
C     NOTE-- COORD. SYSTEM IS X HORIZ. + TO RIGHT, VERTICAL + TO
C            BOTTOM
      DO 10 J=1,JM
      I=J
      IF (X2(J)-Y) 10,70,20
   10 CONTINUE
   20 IF (I.EQ.1) I=2
      KKK=1
   30 T1=TAB(X,X1,T(1,I),IM)
      G11=TAB(X,X1,G1(1,I),IM)
      G21=TAB(X,X1,G2(1,I),IM)
      P1=TAB(X,X1,P(1,I),IM)
      IF (KKK) 50,80,40
   40 J=I
      I=I-1
      KKK=-1
      T2=T1
      G12=G11
      G22=G21
      P2=P1
      GO TO 30
   50 DEL=(Y-X2(I))/(X2(J)-X2(I))
      TS=T1+(T2-T1)*DEL
      DUM=P1+(P2-P1)*DEL
      VAIRH=(G11+(G12-G11)*DEL)/DUM
      VAIRV=-(G21+(G22-G21)*DEL)/DUM
   60 RETURN
   70 KKK=0
      GO TO 30
   80 TS=T1
      VAIRH=G11/P1
      VAIRV=-G21/P1
      GO TO 60
      END
```

```
FUNCTION TAB          73/74    OPT=0 TRACE                        FTN 4.6+439          08/24/79  14.28.13          PAGE    1

                  FUNCTION TAB (X,XX,YY,NTAB)                                          TAB       2
                  DIMENSION XX(1), YY(1)                                               TAB       3
                  F=1.                                                                 TAB       4
                  IF (XX(1).GT.XX(2)) F=-F                                             TAB       5
                  DO 10 J=1,NTAB                                                       TAB       6
                  I=J                                                                  TAB       7
                  IF (F*(XX(I)-X)) 10,40,20                                            TAB       8
               10 CONTINUE                                                             TAB       9
               20 IF (I.NE.1) GO TO 30                                                 TAB      10
                  I=2                                                                  TAB      11
               30 J=I-1                                                                TAB      12
                  DEL=XX(I)-XX(J)                                                      TAB      13
                  IF (DEL.EQ.0.) GO TO 50                                              TAB      14
                  TAB=(YY(I)*(X-XX(J))-YY(J)*(X-XX(I)))/DEL                            TAB      15
                  RETURN                                                               TAB      16
               40 TAB=YY(I)                                                            TAB      17
                  RETURN                                                               TAB      18
               50 WRITE (61,60) X,I,J                                                  TAB      19
                  CALL EXIT                                                            TAB      20
            C                                                                          TAB      21
               60 FORMAT (24H0***ERROR IN ROUTINE TAB,F15.4,2I5)                       TAB      22
                  END                                                                  TAB      23

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM
    4       I        XX          ARRAY REFERENCE OUTSIDE DIMENSION BOUNDS.
```

SUBROUTINE EVAP 73/74 OPT=0 TRACE FTN 4.6+439 08/24/79 14.29.13 PAGE 1

```
      SUBROUTINE EVAP (INTER,I)                                          EVA     2
C     DROPLET EVAPORATION.                                               EVA     3
C     PROGRAMMED 1-22-71 BY M. TAYT.                                     EVA     4
C                                                                        EVA     5
CCCCC THIS ROUTINE IS THE SAME AS IN PROGRAM IMPACT EXCEPT               EVA     6
C             FOR THE CARD CHANGE MARKED CSSS                            EVA     7
C                                                                        EVA     8
C     D,TF,VF,E          ARE INPUT FOR DROP NO. I                        EVA     9
C**** NOTE-- FUEL PROPERTY EQUATIONS ARE ONLY FOR JP4 AND JP5/JP8 ***    EVA    10
C                                                                        EVA    11
      COMMON /INPUT/ KFUEL,DEC,SAP,PPH,TITLE(8)                          EVA    12
      COMMON /DEVAP/ DUMMY(20),D(5),TF(5),VF(5),VREL(5),RN(5),CD(5),DRAG EVA    13
     1(5),FN(5),CP(5),DELC(5),SG(5),RHO(5),DELTF(5),TIMS(5),FMASS(5),AL  EVA    14
     2PHA(5),DELV(5),E(5),DX,W(5),VFSAVE(5),TFSAVE(5),DSAVE(5),ESAVE(5), EVA    15
     3DSTART(5),SGSG60(5),SG60(5),DELM(5),OPTION,VAIRH,VAIRV,SINT,COST,D EVA    16
     4UM1,DUM2                                                           EVA    17
      COMMON /TRAJ/ VFUEL,TFUEL,TFUELF,SGF,FMU,RHOF,PS,PT,TS,TT,DUMMZ0(3 EVA    18
     1),VAIR                                                             EVA    19
      DIMENSION TAIRTB(7), AIRKTB(7), AIRMUT(7), AIRCPT(7)               EVA    20
      DATA TAIRTB/400.,600.,1000.,1500.,2000.,2500.,3000./,AIRKTB/.0114, EVA    21
     1.0165,.0252,.0344,.0422,.0486,.0547/,AIRMUT/1.E-5,1.3E-5,1.885E-5, EVA    22
     22.5E-5,3.015E-5,3.48E-5,3.9E-5/,AIRCPT/.2404,.2409,.249,.2642,.277 EVA    23
     32,.2868,.2531/,NTAB/7/                                             EVA    24
      DATA G,GAMMA,R,PID4,GCG,MLS,PI/32.174,1.4,1545.327,.7853982,3.     EVA    25
     15,.2,3.1415927/                                                    EVA    26
C                                                                        EVA    27
      AIRM=28.966                                                        EVA    28
      CONST1=G*GAMMA*R*TS/AIRM                                           EVA    29
C     CHECK FOR FIRST ENTRY TO ROUTINE (INTER=1)                         EVA    30
      IF (INTER.NE.1) GO TO 10                                           EVA    31
C     ESTIMATE NEXT STATION CONDITIONS                                   EVA    32
      VF2=VF(I)                                                          EVA    33
      TF2=TF(I)                                                          EVA    34
      D2=D(I)                                                            EVA    35
      E2=E(I)                                                            EVA    36
      DSTART(I)=D(I)                                                     EVA    37
      GO TO 20                                                           EVA    38
C     ESTIMATE NEXT STATION CONDITIONS                                   EVA    39
   10 VF2=2.*VF(I)-VFSAVE(I)                                             EVA    40
      TF2=2.*TF(I)-TFSAVE(I)                                             EVA    41
      D2=2.*D(I)-DSAVE(I)                                                EVA    42
      IF (D2.LT.1.E-10) D2=1.E-10                                        EVA    43
      E2=2.*E(I)-ESAVE(I)                                                EVA    44
      IF (E2.GT..99) E2=.99                                              EVA    45
      IF (E2.LT.0.) E2=0.                                                EVA    46
C     INITIALIZE FOR ITERATION ON D                                      EVA    47
   20 KOUNTC=1                                                           EVA    48
      SGRESD=SGRFCT(E(I))                                                EVA    49
      SG(I)=SGFCT(TF(I),SGRESD)                                          EVA    50
      SG60(I)=SGFCT(519.69,SGRESD)                                       EVA    51
      IF (INTER.EQ.1) SGSG60(I)=SG(I)/SG60(I)                            EVA    52
      W(I)=PI/6.*D(I)**3*SG(I)*62.428                                    EVA    53
      DELDG=D2-D(I)                                                      EVA    54
      KOUNTD=0                                                           EVA    55
   30 KOUNTD=1                                                           EVA    56
      DZ=(D(I)+D2)*.5                                                    EVA    57
      CIRCUM=PI*DZ                                                       EVA    58
      TEMPA=PID4*DZ**2                                                   EVA    59
      TEMPD=TEMPA*DZ/1.5                                                 EVA    60
C     INITIALIZE FOR ITERATION ON TF                                     EVA    61
      DELTFG=TF2-TF(I)                                                   EVA    62
      EZ=(E(I)+E2)*.5                                                    EVA    63
      VAPM=VAPMF(EZ)                                                     EVA    64
      SGRESD=SGRFCT(EZ)                                                  EVA    65
C     AVERAGE TEMPERATURES, CALC. PROPERTIES                             EVA    66
   40 TFZ=(TF(I)+TF2)*.5                                                 EVA    67
      TMX=(TS+TFZ)*.5                                                    EVA    68
      PAS=PASF(TFZ,EZ)                                                   EVA    69
      IF (PAS.LT.PS-.01) GO TO 50                                        EVA    70
C     AT BOILING POINT.                                                  EVA    71
      PAS=PS-.01                                                         EVA    72
      KOUNTD=1                                                           EVA    73
   50 VAPK=VAPKF(TMX,VAPM)                                               EVA    74
      VAPMU=VAPMUF(TMX)                                                  EVA    75
      VAPLAM=VAPLMF(TFZ)                                                 EVA    76
      CP(I)=CPFCT(TFZ,SGRESD)                                            EVA    77
      VAPCP=VAPCPF(TMX)                                                  EVA    75
```

```
      SG(I)=SGFCT(TFI,SGRESD)
      FRHO(I)=SG(I)*62.428
      VAPD=VAPDF(TMX,PS)
      IF (VAPD.LT..00005) VAPD=.00005
      ALP=PS/PAS*ALOG(PS/(PS-PAS))
C     AIR PROPERTIES
      AIRK=TAB(TMX,TAIRTB,AIRKTB,NTABAR)
      AIRMU=TAB(TMX,TAIRTB,AIRMUT,NTABAR)
      AIRCP=TAB(TMX,TAIRTB,AIRCPT,NTABAR)
C     DIFFUSION ZONE PROPERTIES
      QK=PAS/PS*.5
      QJ=1.-QK
      QKMX=QJ*AIRK+QK*VAPK
      QMUMX=QJ*AIRMU+QK*VAPMU
      QMMX=QJ*AIRM+QK*VAPM
      QCPMX=(QJ*AIRM*AIRCP+QK*VAPM*VAPCP)/QMMX
      QRHOMX=PS*QMMX*144./R/TMX
      SC=QMUMX/VAPD/QRHOMX
      PR=QCPMX*QMUMX/QKMX*3600.
      TEMPE=DI*QRHOMX/QMUMX
      QMASS=TEMPD*SG(I)*62.428
      TEMPF=.6*SC**.333333333
CCCCCC
      TEMPG=CIRCUM*VAPD*VAPM*PAS*ALP/R/TMX*144.
      TEMPH=.6*PR**.333333333
      TEMPI=VAPCP/CIRCUM/QKMX
      TEMPJ=CIRCUM*QKMX*(TS-TFI)/3600.
      TEMPK=TEMPD*SG(I)*CP(I)*62.428
C     INITIALIZE FOR ITERATION ON VF
      DELVG=VF2-VF(I)
      KOUNTA=1
C     CALCULATE DELTA V FOR DROP
   60 VFZ=(VF(I)+VF2)*.5
      IF (OPTION.EQ.0.) GO TO 70
      VRV=VFZ*SINT-VAIRV
      VRH=VFZ*COST-VAIRH
      VREL(I)=SQRT(VRV**2+VRH**2)
      SPHI=VRV/VREL(I)
      CPHI=VRH/VREL(I)
      VSIGN=1.
      GO TO 80
   70 VREL(I)=VAIR-VFZ
      VSIGN=1.
      IF (VREL(I).GE.0.) GO TO 80
      VREL(I)=-VREL(I)
      VSIGN=-VSIGN
   80 RN(I)=VREL(I)*TEMPE
CCCCCC
      IF (RN(I).LT.22.16) CD(I)=2.0
      IF (RN(I).GE.22.16) CD(I)=27./RN(I)**.84
      IF (RN(I).GT.80.) CD(I)=.271*RN(I)**.217
      IF (RN(I).GT.10000.) CD(I)=2.0
CCCCCC
      FMACH2=VREL(I)**2/CONST1
      TEMPB=PS*(((1.+GM1O2*FMACH2)**GOGM1-1.)
      DRAG(I)=TEMPB*CD(I)*TEMPA*144.
      ALPHA(I)=DRAG(I)/QMASS*VSIGN*G
      IF (OPTION.EQ.0.) GO TO 90
C     MODIFY FOR EFFECT OF G
C$$$  DUM1= G - ALPHA(I) * SPHI
      DUM1=-ALPHA(I)*SPHI
      DUM2=-ALPHA(I)*CPHI
      ALPHA(I)=SQRT(DUM1**2+DUM2**2)
      SINB=DUM1/ALPHA(I)
      COSB=DUM2/ALPHA(I)
   90 TIMS(I)=DX/VF(I)
      DUMMY1=VF(I)**2
      DUMMY2=2.*DX*ALPHA(I)
C     CHECK IF ROUND/OFF ERROR IS A PROBLEM
      IF (ABS(DUMMY2/DUMMY1).LT.1.E-7) GO TO 100
      TIMS(I)=(SQRT(DUMMY1+DUMMY2)-VF(I))/ALPHA(I)
  100 DELV(I)=ALPHA(I)*TIMS(I)
      IF (OPTION.EQ.0.) GO TO 110
      VRV=VRV+DELV(I)*SINB
      VRH=VRH+DELV(I)*COSB
      DUM1=VRV+VAIRV
      DUM2=VRH+VAIRH
```

```
      VF2=SQRT(DUM1**2+DUM2**2)
      GO TO 120
  110 VF2=VF(I)+DELV(I)
C     CHECK IF WITHIN TOLERANCE
  120 IF (ABS(1.-DELVG/DELV(I)).LE..01) GO TO 160
      DELVG=DELV(I)
      IF (ABS(DELVG).LT..01) GO TO 140
      KOUNTA=KOUNTA+1
      IF (KOUNTA.LT.25) GO TO 60
  130 WRITE (61,210) KOUNTA,KOUNTB,KOUNTC,KOUNTD,I
      WRITE (61,220) TF2,VF2,D2,E2
      INTER=-1
      IF (OPTION.NE.0.) GO TO 200
      CALL EXIT
C     HAVE CONVERGED ON VF2.  NOW CALC. DELTA TF, WF
  140 TEMPC=SQRT(RN(I))
      QNUM=2.+TEMPF*TEMPC
      DELW=QNUM*TEMPG
CCCCCC
      IF ((DELW*TIMS(I)).GT.QMASS) DELW=QMASS/TIMS(I)
      QNUH=2.+TEMP4*TEMPC
  150 Z=DELW/QNUH*TEMPI
      ZZ=Z/(EXP(Z)-1.)
      QVZ=QNUH*ZZ*TEMPJ
      IF (KOUNTD.EQ.0) GO TO 170
C     AT BOILING POINT.  ASSUME DELTF= 0.
      IF (VAPLAM.EQ.0.) GO TO 130
      DELWN=QVZ/VAPLAM
CCCCCC
      IF ((DELWN*TIMS(I)).GT.QMASS) DELWN=QMASS/TIMS(I)
      IF (ABS(DELWN-DELW).LE..002*ABS(DELW)) GO TO 160
      DELW=DELWN
      KOUNTD=KOUNTD+1
      IF (KOUNTD.LT.25) GO TO 150
      GO TO 130
  160 IJK=1
      KOUNTD=1
C     AT BOILING POINT, CALC TF2 BASED ON PS AND E2
      TF2=PASF(-PS,E2)
      DELTF(I)=TF2-TF(I)
      GO TO 180
  170 DELTF(I)=(QVZ-DELW*VAPLAM)*TIMS(I)/TEMPE
      TF2=TF(I)+DELTF(I)
CCCCCC
      IF (KFUEL.EQ.4.AND.TF2.GT.1092.8) TF2=1092.8
CCCCCC
      IF (KFUEL.EQ.2.AND.TF2.GT.1210.4) TF2=1210.4
C     CHECK IF WITHIN TOLERANCE
  180 IF (ABS(DELTF(I)-DELTFG).LE..01*ABS(DELTF(I))) GO TO 190
      DELTFG=DELTF(I)
      IF (ABS(DELTFG).LT.1.) GO TO 190
      KOUNTB=KOUNTB+1
      IF (KOUNTB.LT.25) GO TO 40
      GO TO 130
C     HAVE CONVERGED ON TF2.  NOW CALC. DELTA D
  190 IJK=0
      W2=W(I)-DELW*TIMS(I)
      IF (W2.LT.1.E-30) W2=1.E-30
      SGRESD=SGRFCT(E2)
      SG(I)=SGFCT(TF2,SGRESD)
      SG60(I)=SGFCT(519.69,SGRESD)
      D2=(6.*W2/PI/SG(I)/62.428)**.3333333333
      IF (D2.LT.1.E-10) D2=1.E-10
      E2=1.-(D2/DSTART(I))**3*SG(I)/SG60(I)/SGSG60(I)
      IF (E2.GT..99) E2=.99
      IF (E2.LT.0.) E2=0.
      DELD=D2-D(I)
C     CHECK IF WITHIN TOLERANCE
      IF (ABS(1.-DELDG/DELD).LE..01) GO TO 200
      DELDG=DELD
      IF (ABS(DELDG).LT.1.E-7) GO TO 200
      KOUNTC=KOUNTC+1
      IF (KOUNTC.LT.20) GO TO 30
      GO TO 130
C     HAVE CONVERGED ON ALL PARAMETERS FOR THIS INTERVAL
C     SAVE OLD CONDITIONS, SET NEW ONES
  200 VFSAVE(I)=VF(I)
```

```
      SUBROUTINE EVAP       73/74    OPT=0 TRACE                FTN 4.6+439        09/24/79  14.29.13        PAGE     4

               WF(I)=WF2                                                     EVA     233
               TFSAVE(I)=TF(I)                                               EVA     234
               TF(I)=TF2                                                     EVA     235
               DSAVE(I)=D(I)                                                 EVA     236
               D(I)=D2                                                       EVA     237
               ESAVE(I)=E(I)                                                 EVA     238
               E(I)=E2                                                       EVA     239
               DELD(I)=DWZ*TIMS(I)                                           EVA     240
               DELP(I)=DELW*TIMS(I)                                          EVA     241
               RETURN                                                        EVA     242
C                                                                            EVA     243
          210  FORMAT (18H0**** EVAP FAILURE,4I5,5X,7HDROPLET I5)            EVA     244
          220  FORMAT (4E15.5)                                               EVA     245
               END                                                           EVA     246
```

```
FUNCTION PASF       73/74    OPT=0 TRACE                  FTN 4.6+439        08/24/79  14.28.13        PAGE     1

          FUNCTION PASF (T,E)                                                     PAS      2
C         T= TEMPER. (R), E= FRACTION EVAPORATED                                  PAS      3
C         PASF= FUEL VAPOR PRESSURE (PSIA) FOR JP4, JP5/JP8                       PAS      4
          COMMON /INPUT/ KFUEL,DEQ,SAP,PPH,TITLE(8)                               PAS      5
          DIMENSION CK1(7,4), CK2(7,4), ETAB(7)                                   PAS      6
          DATA ETAB/0.,.1,.3,.5,.7,.9,1.0/,CK1/0.,0.,0.,0.,0.,0.,0.,155810.,     PAS      7
         1386390.,585230.,617550.,1321290.,3175400.,10497000.,0.,0.,0.,0.,0.     PAS      8
         2,0.,0.,40497.,136750.,294430.,604200.,1399600.,7044100.,77680000./     PAS      9
         3,CK2/0.,0.,0.,0.,0.,0.,0.,7414.8,8548.4,9066.7,9494.0,10093.,11178     PAS     10
         4.,12670.,0.,0.,0.,0.,0.,0.,0.,4816.,5259.,7151.,8042.,9045.,10974.     PAS     11
         5,13839./                                                                PAS     12
C                                                                                 PAS     13
          IF (KFUEL.NE.2.AND.KFUEL.NE.4) GO TO 110                                PAS     14
C         IF (T .LT. 0 , ARGUMENT IS (-PSI).  FIND AND RETURN CORRES. TEMPERA     PAS     15
          PSTAT=-T                                                                PAS     16
          DO 10 J=1,7                                                             PAS     17
          I=J                                                                     PAS     18
          IF (E-ETAB(J)) 20,80,10                                                 PAS     19
       10 CONTINUE                                                                PAS     20
          GO TO 30                                                                PAS     21
       20 IF (I.EQ.1) I=2                                                         PAS     22
       30 K=1                                                                     PAS     23
       40 IF (PSTAT.LT.0.) GO TO 50                                               PAS     24
          PASF=CK2(I,KFUEL)/ALOG(CK1(I,KFUEL)/PSTAT)                              PAS     25
          GO TO 60                                                                PAS     26
       50 PASF=CK1(I,KFUEL)*EXP(-CK2(I,KFUEL)/T)                                  PAS     27
       60 IF (K) 100,90,70                                                        PAS     28
       70 PSAVE=PASF                                                              PAS     29
          J=I                                                                     PAS     30
          I=I-1                                                                   PAS     31
          K=-1                                                                    PAS     32
          GO TO 40                                                                PAS     33
       80 K=0                                                                     PAS     34
          GO TO 40                                                                PAS     35
       90 RETURN                                                                  PAS     36
      100 PASF=PASF+(PSAVE-PASF)/(ETAB(J)-ETAB(I))*(E-ETAB(I))                    PAS     37
          GO TO 90                                                                PAS     38
      110 WRITE (61,120) KFUEL                                                    PAS     39
          CALL EXIT                                                               PAS     40
C                                                                                 PAS     41
      120 FORMAT (25H0PASF CANNOT HANDLE FUEL=I5)                                 PAS     42
          END                                                                     PAS     43
```

```
FUNCTION VAPCPF      73/74    OPT=0 TRACE                        FTN 4.6+439        08/24/78  14.28.13        PAGE    1

                  FUNCTION VAPCPF (T)
          C       T= TEMPER. (R), VAPCPF= CP FOR JP4, JP5/JP8 FUEL VAPOR      PROP     2
                  COMMON /INPUT/ KFUEL,DEQ,GAP,PPM,TITLE(8)                   PROP     3
                  IF (KFUEL.EQ.2) GO TO 10                                    PROP     4
                  VAPCPF=.180+.000565*T                                       PROP     5
                  GO TO 20                                                    PROP     6
               10 VAPCPF=.069+.000530*T                                       PROP     7
               20 RETURN                                                      PROP     8
                  END                                                         PROP     9
                                                                              PROP    10
```

```
                FUNCTION VAPMUF (T)                                     PROP      11
C               T= TEMPER. (R), VAPMUF= M3 FOR JP4, JP5/JP8 FUEL VAPOR  PROP      12
                COMMON /INPUT/ KFUEL,DEG,GAP,PPH,TITLE(8)               PROP      13
                IF (KFUEL.EQ.2) GO TO 10                                PROP      14
                VAPMUF=808.E-9+7.64E-9*T                                PROP      15
                GO TO 20                                                PROP      16
             10 VAPMUF=248.E-9+6.31E-9*T                                PROP      17
             20 RETURN                                                  PROP      18
                END                                                     PROP      19
```

```
FUNCTION VAPKF       73/74   OPT=0 TRACE                    FTN 4.6+439         08/24/78  14.28.13        PAGE    1

                FUNCTION VAPKF (T,W)
        C       T= TEMPER. (R), VAPKF= K FOR FUEL VAPOR
        C       W= MOLECULAR WEIGHT
                DIMENSION WTAB(4), ATAB(4), BTAB(4), TABK(4)
                DATA WTAB/50.,100.,150.,300./,NTAB/4/,ATAB/-.006362,-.006358,-.006
               1284,-.006019/,BTAB/.0000297,.0000273,.0000290,.0000235/
        C
                DO 10 I=1,NTAB
             10 TABK(I)=ATAB(I)+BTAB(I)*T
                VAPKF=TAB(W,WTAB,TABK,NTAB)
                RETURN
                END
```

```
FUNCTION SGFCT      73/74    OPT=0 TRACE                FTN 4.6+439         08/24/78  14.29.13        PAGE     1

                  FUNCTION SGFCT (T,SG60R)                                         PROP      32
            C     SG60R =  SG RESIDUE AT 60 DEG F                                  PROP      33
            C     T= TEMPER. (R), SGFCT= SG FOR JP4 AND JP5 LIQUID FUEL            PROP      34
                  SGFCT=SG60R+.200-.0004*T                                         PROP      35
                  RETURN                                                           PROP      36
                  END                                                              PROP      37
```

FUNCTION SGRFCT   73/74   OPT=0 TRACE   FTN 4.6+439   08/24/79 14.28.13   PAGE   1

```
      FUNCTION SGRFCT (E)                                             PROP    38
C     E= FRACTION EVAPORATED, SG60= SG AT 60 DEG F                    PROP    39
C     SGRFCT= SG RESIDUE AT 60 DEG F FOR JP4, JP5/JP8 LIGNIC FUEL     PROP    40
      COMMON /INPUT/ KFUEL,DE0,GAP,PPM,TITLF(8)                       PROP    41
      DATA SG604/.775/,SG6058/.806/                                   PROP    42
      SG60=SG604                                                      PROP    43
      IF (KFUEL.NE.4) SG60=SG6058                                     PROP    44
      SGRFCT=1.076/((1.076/SG60-1.)*(1.-.67*E)+1.)                    PROP    45
      RETURN                                                          PROP    46
      END                                                             PROP    47
```

```
      FUNCTION VAPDF (T,P)                                          PROP 48
C     T= TEMPER. (R) , P= STATIC PRESSURE                           PROP 49
C     VAPDF= DIFFUSIVITY FOR HEPTANE-OXYGEN                         PROP 50
      VAPDF=2.083/P*(T*(T*1.1319E-9+1.979E-6)-9.915E-4)            PROP 51
      RETURN                                                        PROP 52
      END                                                           PROP 53
```

```
      FUNCTION VAPMF (E)                                                 PROP      54
C     E= FRACTION EVAPORATED, VAPMF= MOLECULAR WEIGHT OF JP4, JP5/JP8    PROP      55
C                       FUEL VAPOR                                       PROP      56
      COMMON /INPUT/ KFUEL,DEQ,SAR,PP4,TITLE(8)                          PROP      57
      DIMENSION ETAB(7), TABMV(7,4)                                      PROP      58
      DATA ETAB/0.,.1,.3,.5,.7,.9,1.0/,NTAB/7/,TABMV/0.,0.,0.,0.,0.,0.,0 PROP      59
     1.,148.12,163.29,169.88,175.04,187.25,194.96,211.07,0.,0.,0.,0.,0., PROP      60
     20.,0.,93.26,114.60,126.51,139.16,155.49,173.21,204.76/             PROP      61
C                                                                        PROP      62
      VAPMF=TAB(E,ETAB,TABMV(1,KFUEL),NTAB)                              PROP      63
      RETURN                                                             PROP      64
      END                                                                PROP      65
```

```
      FUNCTION VAPLHF (T)
C     T= TEMPER (R), VAPLHF= LATENT HEAT OF VAPORISATION FOR JP4,BTU/LB
C            ALSO, JP5/JP8
      COMMON /INPUT/ KFUEL,DEO,SAP,PP4,TITLE(9)
      IF (KFUEL.EQ.2) GO TO 10
      VAPLHF=0.
      IF (T.LT.1092.88) VAPLHF=13.20*(1092.88-T)**.38
      GO TO 20
   10 VAPLHF=0.
      IF (T.LT.1210.45) VAPLHF=10.75*(1210.45-T)**.41
   20 RETURN
      END
```

```
FUNCTION CPFCT      73/74    OPT=0 TRACE                    FTN 4.6+439        08/24/78  14.20.13        PAGE     1

            FUNCTION CPFCT (T,SGR60)                                           PROP      78
      C     T= TEMPER (R), CPFCT, CP FOR LIQUID JP4, JP5/JP8                   PROP      79
      C     SGR60= SG RESIDUE AT 60 DEG F FOR JP4                              PROP      80
            CPFCT=(.181+.00045*T)/SQRT(SGR60)                                  PROP      81
            RETURN                                                             PROP      82
            END                                                                PROP      83
```

```
      SUBROUTINE SCALES (MAX,MIN,LENGTH,STEP,START)                      SCA     2
      REAL MAX,MIN,LENGTH                                                SCA     3
      DIMENSION FACTOR1(11)                                              SCA     4
      DATA FACTOR1/.001,.00125,.0015,.00175,.002,.0025,.003,.004,.005,.0 SCA     5
     106,.0075/                                                          SCA     6
      FACT=.001                                                          SCA     7
      DO 20 I=1,12                                                       SCA     8
      FACT=FACT*10.                                                      SCA     9
      DO 10 J=1,11                                                       SCA    10
      STEP=FACTOR1(J)*FAC,                                               SCA    11
      ITE=MAX/STEP                                                       SCA    12
      ITS=MIN/STEP                                                       SCA    13
      IF (ITE.LT.0) ITE=ITE-1                                            SCA    14
      IF (ITS.LT.0) ITS=ITS-1                                            SCA    15
      DELT1=FLOAT(ITE+1-ITS)*STEP                                        SCA    16
      DELT2=STEP*LENGTH                                                  SCA    17
      IF (DELT2.GE.DELT1) GO TO 30                                       SCA    18
   10 CONTINUE                                                           SCA    19
   20 CONTINUE                                                           SCA    20
      WRITE (61,40) MAX,MIN                                              SCA    21
      RETURN                                                             SCA    22
   30 N6=IFIX(MIN/STEP)                                                  SCA    23
      IF (N6.LE.0.AND.MIN.LT.0.0) N6=N6-1                                SCA    24
      START=FLOAT(N6)*STEP                                               SCA    25
      RETURN                                                             SCA    26
C                                                                        SCA    27
C                                                                        SCA    28
   40 FORMAT (///44H VARIABLES OUTSIDE RANGE OF SUBROUTINE SCALE,//10X,6 SCA    29
     1HMAX = ,E12.4,10X,6HMIN = ,E12.4)                                  SCA    30
      END                                                                SCA    31
```

821-79

DEPARTMENT OF THE ARMY

Applied Technology Laboratory
U.S. Army Research and Technology
Laboratories (AVRADCOM)
DAVDL-ATL-TSD
Fort Eustis, Virginia 23604

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE ARMY
DOD-314

FOURTH CLASS